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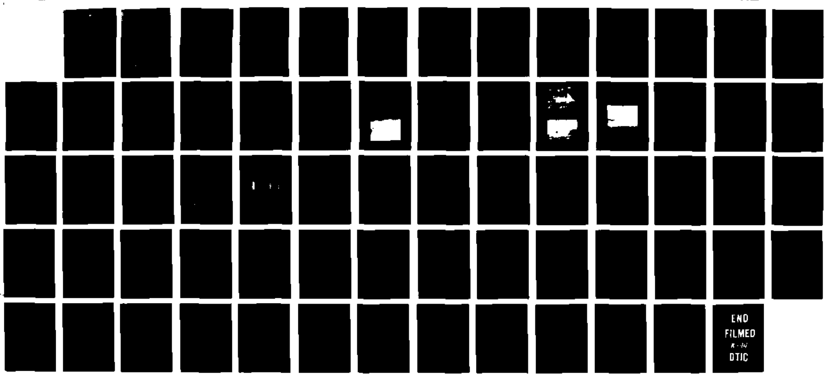

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USACERL Technical Report EC-94/25
July 1994

Noise Level Reduction of .50 Caliber Gunfire by Terrain Shielding

by
Larry L. Pater, Raman Yousefi, and Walter Alvendia

Gunfire at Army rifle ranges is an unavoidable part of military training that can disturb the surrounding community and become a source of complaint. Barriers can effectively screen noise in some scenarios, and are useful in reducing noise from small arms fire because acoustic energy from this noise source is concentrated at relatively high frequencies, making barriers of modest size large in terms of wavelength and capable of providing significant noise shielding.

Larger guns exhibit more acoustic energy at lower frequencies, and therefore require much larger barriers to achieve effective noise reduction. This study investigated the reduction of .50 caliber machine gun noise by using terrain features as noise barriers. Measurements and calculations showed that berms and ridges can yield significant reduction of .50 caliber machine gun noise. A 3 m high berm yielded about 5 to 10 dB reduction in A-weighted sound exposure levels (ASEL) directly to the rear, while a roughly 10 m high berm yielded from 10 to over 20 dB reduction. The study concludes that propagation conditions and excess ground attenuation can also significantly affect achieved barrier insertion loss, and suggests noise mitigation strategies.

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Larger guns exhibit more acoustic energy at lower frequencies, and therefore require much larger barriers to achieve effective noise reduction. This study investigated the reduction of .50 caliber machine gun noise by using terrain features as noise barriers. Measurements and calculations showed that berms and ridges can yield significant reduction of .50 caliber machine gun noise. A 3 m high berm yielded about 5 to 10 dB reduction in A-weighted sound exposure levels (ASEL) directly to the rear, while a roughly 10 m high berm yielded from 10 to over 20 dB reduction. The study concludes that propagation conditions and excess ground attenuation can also significantly affect achieved barrier insertion loss, and suggests noise mitigation strategies.

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This research was done for Headquarters, U.S. Army Europe, Seventh Army (HQ USAREUR/7A), ODCSENGR, FE Division, Environmental Branch, under Reimbursable Project Order No. FE 67-90. The technical monitor was CPT Yake, AEAEN-FE-E.

The work was done by the Environmental Compliance Modeling and Simulation Division (EC), Environmental Sustainment Laboratory (EL), U.S. Army Construction Engineering Research Laboratories (USACERL). The USACERL principal investigator was Dr. Larry Pater. Thanks is expressed to Dr. George Swenson and Dr. Michael White, CECER-ECA, and Kenneth Eldred, of Ken Eldred Engineering, for their interest, ideas, and discussion during the project. The Michigan National Guard and the personnel of Camp Grayling, MI are gratefully acknowledged for their generous cooperation in carrying out the experiments. Dr. John Bandy is Chief, CECER-EC, and William Goran is Chief, CECERL-EL. The USACERL technical editor was William J. Wolfe, Information Management Office.

LTC David J. Rehbein is Commander and Acting Director, USACERL. Dr. Michael J. O'Connor. is Technical Director.

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NOISE LEVEL REDUCTION OF .50 CALIBER GUNFIRE BY TERRAIN SHIELDING

1 INTRODUCTION

Background

The U.S. Army Construction Engineering Research Laboratories (USACERL) is engaged in a continuing effort to mitigate noise disturbance to the surrounding community caused by military training and testing activities. Successful noise mitigation requires information regarding the noise source characteristics, the propagation of the noise from the source to the receiver, and the perception of the noise by the receiver. Analytical and experimental investigations by the USACERL Environmental Acoustics Team have provided information regarding these topics, including specific noise mitigation procedures and devices applicable to reducing Army training noise.

For example, one general guideline to lessen the total number of noise complaints is to schedule noisy activities during the middle of the day, rather than at night or early in the morning, to take advantage of propagation conditions that often result in lower community noise levels. A more effective noise mitigation procedure is to predict and/or monitor the noise level at specific geographical locations. Accurate noise level prediction must account for the effect of factors such as atmospheric temperature and wind structure on propagation of source noise. The resulting noise level information can be used along with human noise response criteria to plan or modify activity schedules and land use. An effective noise mitigation program also requires maintenance of an accurate log of noise-producing activities and noise complaints.

Barriers can effectively screen noise in some scenarios (Swenson et al. 1990). A barrier interposed between source and observer does not achieve a total acoustical shadow because some sound energy is diffracted around the barrier into the shadow zone. The amount of diffraction that occurs depends on the frequency of the sound; the lower the frequency, the more a sound tends to diffract around the barrier edge, resulting in less noise reduction. Barriers are of particular utility for small arms because the acoustic energy is concentrated at relatively high frequencies. Barriers of modest size are quite large in terms of wavelength, and can thus provide significant noise shielding. Larger guns exhibit a greater portion of their energy at lower frequencies, so that a larger, more expensive barrier is required to achieve effective noise mitigation. Research is needed to determine methods to reduce the noise created by larger caliber gunfire, e.g., .50 caliber machine gun fire.

Purpose

The objective of the current investigation is to obtain information regarding the use of terrain features, specifically berms and ridges, as barriers to reduce the noise created by firing a .50 caliber machine gun. The ultimate motivation for this noise mitigation effort is to help the Army maintain its training capability.

Approach

Experiments were performed at Camp Grayling, MI, a National Guard installation. Two existing terrain features were used as noise barriers: (1) a constructed earth berm about 3 m high, and (2) a natural ridge about 10 m high. Measurements were made of the noise level reduction due to the berms under several wind conditions, using the muzzle blasts of .50 caliber machine guns as sound sources. Measurements were also made to investigate the effect of excess ground attenuation of sound energy at the test site. These measurements were used to help interpret the insertion loss measurements. The resultant data were analyzed and compared with theoretical predictions.

Mode of Technology Transfer

The results of this study will be furnished directly to the sponsors of this project, and to the Army Environmental Hygiene Agency (AEHA) for immediate use in planning and design of firing ranges and training doctrine. It is also anticipated that the results of this study will be incorporated into a technical manual for mitigation of Army noise sources.

2 EXPERIMENTAL ARRANGEMENT AND PROCEDURES

The basic experimental plan was to record .50 caliber gun noise with and without a barrier interposed between the gun and the recording microphones. This was accomplished by using two gun locations, with and without a barrier, with duplicate arrays of sound level instrumentation at specific locations relative to each gun location. The array that featured clear lines of sight from gun to instrumentation provided reference noise levels against which to compare noise levels measured by the instrumentation located in the acoustic shadow of a barrier. Several experimental configurations were used to obtain data for various combinations of two barrier heights and two gun muzzle heights. The two barriers (the "low berm" and "high berm") were existing earth berms located at Camp Grayling, MI. The two gun muzzle heights corresponded with two different types of gun mounts: tripod ground mounts and a vehicle ring mount. Fortuitous weather resulted in data for different wind directions. A complete list of the experiments that were carried out is presented in Table 1.

The "low berm" was located on Range 37 at Camp Grayling, MI. Figure 1 shows the microphone array locations used for the low berm experiments;* Table 2 details the location, including relative elevations of the ground surface. The relative elevations given in Table 2 are of the ground, not including source receiver height above the ground. Note that microphones (Mics) L4 and L7 serve as part of the arrays for both guns. Microphone locations L6, L7, and L8 were displaced 7 m to maintain L8 a minimum of 5 m from a 1-m deep depression. The berm was about 100 m long, 3 m high and 15 m wide at the base with a relatively flat top about 3 m wide, and was fairly uniform in cross-section. It was a man-made berm composed of very sandy soil indigenous to the area, originally constructed to conceal the mechanical works of a moving pop-up target for tank gunnery training. Figure 2 shows a plan of the berm with elevations of selected locations along the top of the berm. Figure 3 shows a cross-section of the berm along the line of fire and also shows the locations of the shielded ("B") gun and microphones L2 and L4. Mic L2 was located to monitor the sound field at the top of the barrier, as recommended by ANSI Standard S12.8-1987, while Mic L1 was located at the corresponding location behind the unshielded ("A") gun. The front (downrange) face of the berm was sparsely vegetated by weeds and was fairly steep. The back face of the berm and the field behind the berm in which the microphones were located was characterized by very sandy soil with fairly dense vegetation consisting of weeds about 0.5-m tall, and occasional small bushes about 1-m tall. Figure 4 shows typical ground cover.

The "high berm" was located on Range 35 at Camp Grayling, MI. It was a natural formation about 250 m long and 10 m high. The general shape of the berm is shown by means of contour lines (10-ft contour interval) in Figure 5. The locations of the microphones and guns are also shown in Figure 5; the range and elevation of each microphone location are given more accurately in Table 3. The relative elevations given are of the ground, not including source or receiver height above the ground. Figure 6 shows berm cross-sections. The entire area, including the surface of the berm, was characterized by very sandy soil with a fairly dense cover of weeds about 0.5-m tall and bushes about 1-m tall. Figure 4 shows typical ground cover. There were widely-spaced medium-sized trees on the top and back side of the berm. The basic downrange direction of fire shown in Figure 5 (designated as 0 degrees DOF) was 70 degrees magnetic. The microphones were located along azimuths of 90 and 120 degrees clockwise from this basic downrange direction of fire. Some firing was done "crossrange" at an azimuth of 270 degrees clockwise from the basic direction of fire, into bullet traps consisting of sandbags backed up by a 3 m high pile of sandy soil to stop the bullets with a very large margin of safety. Only limited firing was done in this direction, and extreme safety precautions were used. These 270-degree firings yielded data at azimuths of 180 and 210 degrees from the direction of fire, with the berm behind rather than to the side of the gun,

*Figures are shown at the end of their corresponding chapter.

Table 1

Camp Grayling Barrier Experiments

Date*	Time	Expt No.**	No. Rds.	Wind Dir.	Wind Speed	Berm	Gun Mount***	DOF†	Gun Loc.	Remarks
6/11/91	1010	3B	10	180	0-5	High	T	0	B	
6/11/91	1020	3A	10	180	0-2	High	T	0	A	
6/11/91	1030	4B	10	180	0-5	High	T	0	B	Repeat 3B
6/11/91	1038	5B	10	180	0-5	High	T	270	B	
6/11/91	1056	7	21	180	0-5	High	T	270	A&B	
6/11/91	1322	11B	10	270	5-10	High	R	0	B	
6/11/91	1337	12A	10	270	5-10	High	R	0	A	
6/11/91	1345	12B	4	270	5-10	High	R	0	B	
6/12/91	1013	3	21	280	5-10	Low	T	0	A&B	
6/12/91	1254	6B	10	250	10-15	High	R	0	B	Non-paired wind
6/12/91	1310	6A	10	0	10-15	High	R	0	A	
6/12/91	1320	7B	10	0	10-15	High	R	0	B	
6/12/91	1356	8B	10	0	10-15	High	T	0	B	Non-paired wind
6/12/91	1415	7A	10	180	15-20	High	T	0	A	Non-paired wind
6/13/91	1145	2B	10	90	5-10	High	R	0	B	
6/13/91	1155	3A	10	90	5-10	High	R	0	A	
6/13/91	1204	4A	10	90	5-10	High	R	0	A	
6/13/91	1230	5A	10	90	5-10	High	T	0	A	
6/13/91	1240	4B	10	90	5-10	High	T	0	B	
6/13/91	1423	12	19	90	5-10	Low	T	0	A&B	
6/29/91	1023	3A	21	70	0-5	High	R&T	0	A	Path height
6/29/91	1028	4A	10	70	0-6	High	T	0	A	Path height
6/29/91	1050	5A	20	70	0-10	High	R&T	0	A	Path height
6/29/91	1233	8B	10	150	5-10	High	R	0	B	
6/29/91	1241	8A	10	150	5-7	High	R	0	A	
6/29/91	1308	9B	10	150	5-8	High	T	0	B	
6/29/91	1315	9A	10	150	3-8	High	T	0	A	
6/29/91	1330	10	21	150	3-8	High	T	270	A&B	
6/29/91	1420	15A	18	150	3-8	High	T	0	A	Gun comparison
6/29/91	1432	16A	20	150	5-8	High	R&T	0	A	Path height
6/30/91	1038	21	21	45	3-7	Low	T	0	A&B	
6/30/91	1052	22	12	45	7	Low	T	0	A&B	Rapid fire

* Wind direction is given as the azimuthal direction from which the wind was blowing, measured clockwise from the basic direction of fire. Wind speed is given in miles per hour (mph). Both speed and direction were estimated the first 3 days and measured the last 2 days, at a location near the gun location.

** A = unshielded gun location; B = shielded gun location

*** R = ring mount; T = tripod mount

† DOF = direction of fire

Table 2

Microphone Locations for Low Berm

	Referenced to "A" Gun:			Referenced to "B" Gun: (elev -0.43 m re A Gun)		
Mic No.	**Azimuth (Deg)**	**Range (m)**	**Elev. (m)**	**Azimuth (Deg)**	**Range (m)**	**Elev. (m)**
L1	180.0	7	+0.00	*	*	*
L2	*	*	*	180.0	7	+3.00
L3	180.0	53	-0.15	*	*	*
L4	240.0	106	-0.23	180.0	53	+0.20
L5	*	*	*	240.0	106	+1.76
L6	177.5	159	-0.18	*	*	*
L7	208.1	180	-0.37	177.5	159	+0.06
L8	*	*	*	208.1	180	+1.15

Note: Relative elevations are of the ground, not including source or receiver heights. "*" indicates "noise data not used for paired comparisons."

Table 3

Microphone Locations for High Berm

	Referenced to "A" Gun:			Referenced to "B" Gun:		
Mic No.	**Azimuth (Deg)**	**Range (m)**	**Elev. (m)**	**Azimuth (Deg)**	**Range (m)**	**Elev. (m)**
H1	*	*	*	90.0	50	+9.91
H2	*	*	*	90.0	128	+3.53
H4	*	*	*	120.0	50	+8.23
H5	*	*	*	120.0	128	+1.96
H7	90.0	50	-0.77	*	*	*
H8	90.0	128	+1.45	*	*	*
H10	120.0	50	-0.42	*	*	*
H11	120.0	128	+0.50	*	*	*

Note: Relative elevations are of the ground, not including source or receiver heights. "*" indicates "noise data not used for paired comparisons."

since the microphones were not moved. Microphones H1 and H4 were located at the top of the berm along each azimuth to monitor the sound field along the top edge of the barrier, and H7 and H10 were located at corresponding locations relative to the unshielded gun. Mics H8 and H11 provided the unshielded gun reference noise levels against which to compare the noise levels measured by Mics H2 and H5 in the acoustic shadow of the berm.

Safety

In addition to the bullet traps, other safety precautions used during the experiment included gunnery range safety briefings and hearing protection for all personnel. Radio communication was in use among all field personnel and with Camp Grayling Range Control at all times. Range safety procedures were stringently observed at all times, including the provision that anyone could call a cease fire at any time. At no time were any personnel permitted forward of the muzzle of a loaded gun. The gunners were experienced weapons handlers who loaded and fired only upon the order of the Range Officer in Charge. All firing was jointly planned by and closely coordinated among Range Control, the Range Officer in Charge, and the Test Director, and was carried out per established Camp Grayling gunnery range safety procedures.

Noise Sources

The noise sources for the experiments were identical M2 machine guns firing recently produced ball ammunition randomly selected from the same production lot. Guns were used as the noise sources because a gun exhibits source directivity, source strength, transient waveform, and energy spectrum that are difficult to simulate. Two different gun muzzle heights corresponded with two different types of gun mounts; tripod ground mounts with a muzzle height of about 0.35 m (Figure 7); and a ring mount on a M548 Cargo Carrier tracked vehicle, with a muzzle height of about 3.15 m (Figure 8). The actual position of a gun muzzle was only known within several centimeters because of gun recoil and ground surface irregularities.

In general, a number of noise events are associated with gun fire, including several minor ones such as propellant gas escaping at locations other than the muzzle, bullet wake noise, noise from actuation of the gun action, and noise due to the bullet impacting a target. At locations well away from the gun, the most important noise events are normally the muzzle blast noise due to the propellant gases exiting from the barrel and a bow shock (sonic boom) associated with a supersonic projectile. The bow shock noise exists only in a portion of the noise field forward of the gun (Eldred 1990; Pater 1981). Bow shock noise was not an issue during this investigation because no measurements were made in the portion of the blast field where bow shock exists. The noise event of primary interest in the present experiment was the muzzle blast noise, since it is usually the greatest offender and is the noise event that can be most usefully mitigated by a barrier.

Experimental Configuration

Four basic experimental configurations were used to investigate various combinations of berm height, muzzle height, and azimuth from the direction of fire. These were:

1a. Berm: Low (Range 37)
 b. Gun Mount: Tripod
 c. Direction of fire: Downrange (0 degrees DOF), perpendicular to berm

2a. Berm: High (Range 35)
b. Gun Mount: Tripod
c. Direction of fire: Downrange (0 degrees DOF), parallel to berm

3a. Berm: High (Range 35)
b. Gun Mount: Ring on vehicle
c. Direction of fire: Downrange (0 degrees DOF), parallel to berm

4a. High (Range 35)
b. Mount: Tripod
c. Direction of fire: Cross-range (270 degrees DOF), perpendicular to berm, into bullet traps.

As has been mentioned above, the basic procedure used to determine the effect of a berm on noise level was to measure the sound levels of two guns, one shielded by the berm (the "B" gun) and one with a clear line of sight from gun to microphone (the "A" gun). The experimental layout and procedures were selected to minimize differences in propagation conditions for the two guns. An effort was made to maintain similar soil characteristics and vegetation cover for the microphone arrays of the two guns. At least 10 rounds were fired from each gun, and the results averaged to minimize the effects of sound level variations due to transient phenomena such as wind gusts and turbulence, which might cause only a momentary variation in continuous noise, but which can have a large effect on the measurement of the short duration impulsive noise of guns. For the low berm experiments and the high berm 270 degrees firings (both of which used tripod gun mounts only), the two guns were fired alternately at intervals of several seconds in an effort to obtain similar average propagation conditions. Safety considerations precluded this procedure for the 0 degree high berm firings (both tripod and ring mounts) since the B gun was located downrange of the A gun (Figure 5). Instead, 10 rounds were fired from each gun location as closely together in time as could be safely managed. For the experimental configurations that used the vehicle ring mount, the same gun was used at both the A and B gun locations, and the vehicle was moved between the two locations.

Additional experiments were conducted to investigate the effect of "excess ground attenuation" on propagation of the impulsive noise signatures, to aid in interpretation of the data from the experiments described above. This experiment used two source heights and three receiver heights. Two guns were located at the A gun location of the high berm layout (Figure 5), one on a tripod mount and the other on the vehicle mount, to achieve source heights of 0.33 m and 3.15 m. At microphone location H8, a total of three sound measurement systems were located at receiver heights of 0.33, 1.30, and 3.15 m (Figure 9). The two guns were fired alternately in single fire at intervals of several seconds. Immediately after this experiment was completed, the vehicle was moved well away (at least 100 m) and a series of rounds was fired from the tripod mount gun to determine if the proximity of the vehicle had a significant effect on the signature of the tripod mount gun.

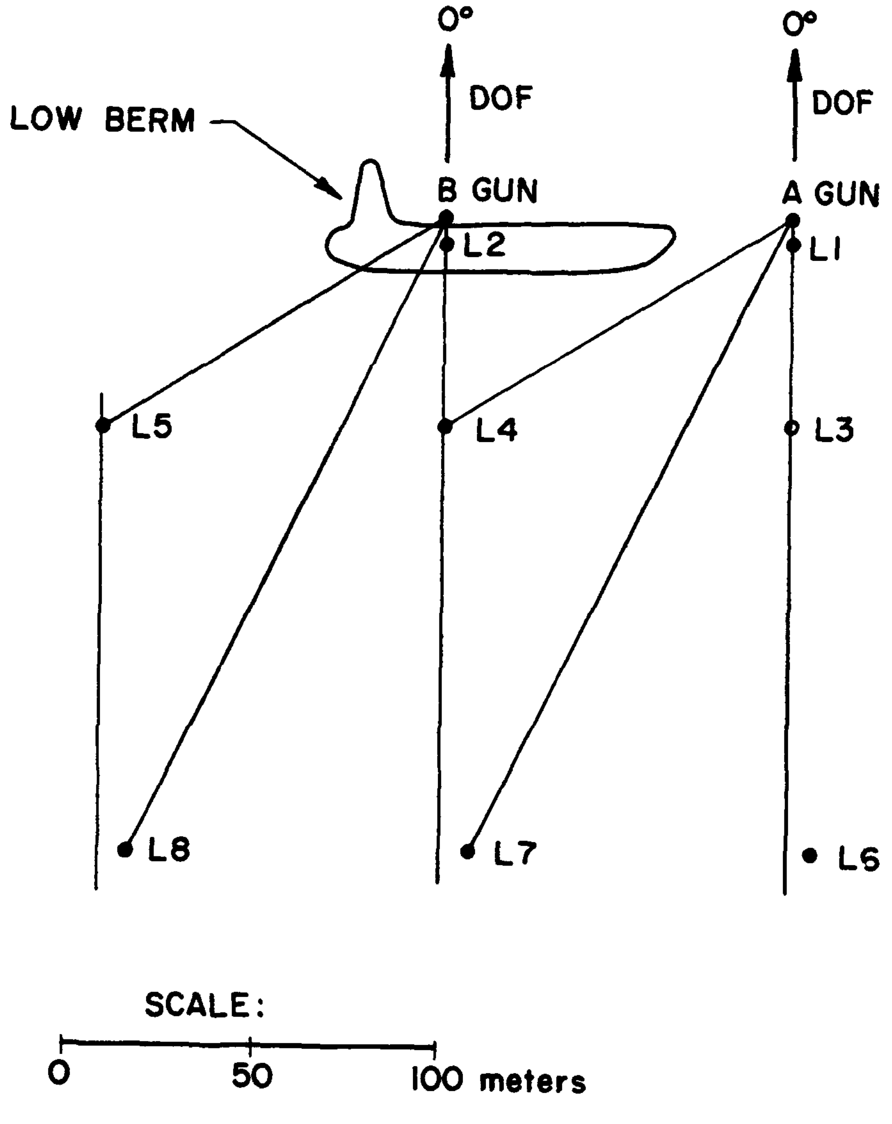


Figure 1. Low Berm Microphone Array.

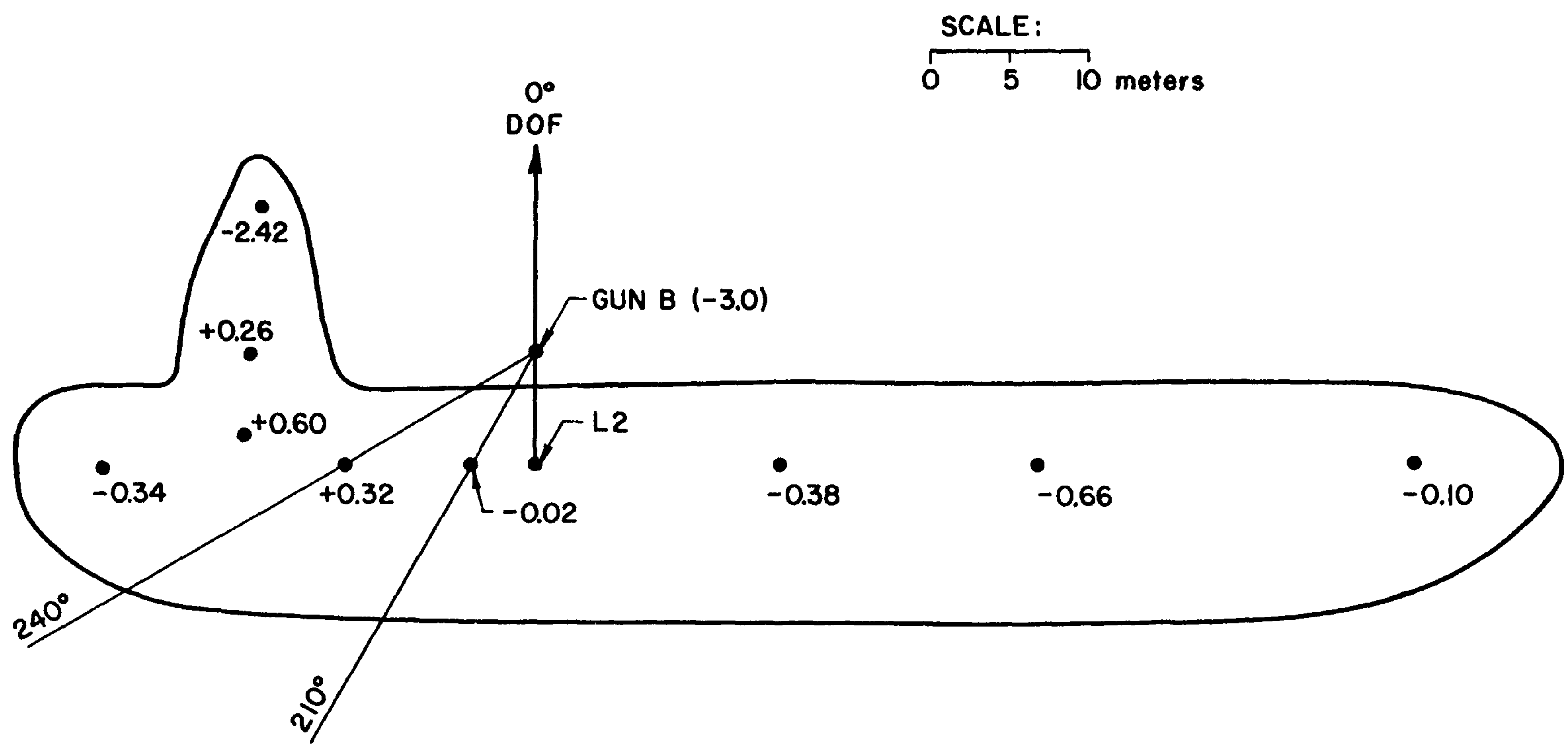


Figure 2. Plan for Low Berm Showing Elevations Relative to Microphone Location L2.

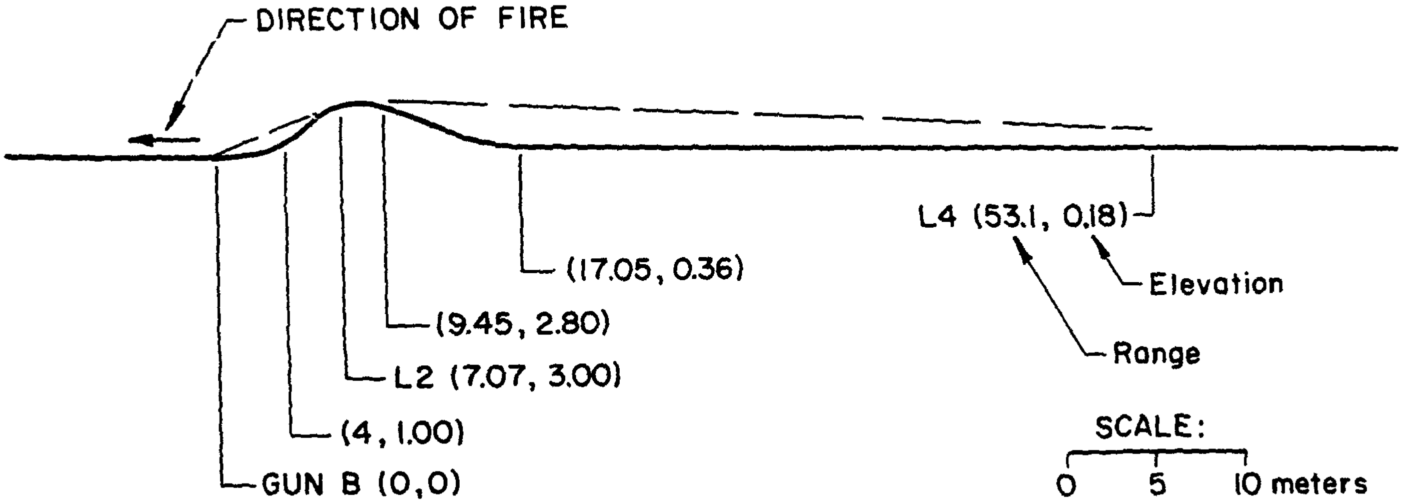


Figure 3. Cross-Section of Low Berm 180 Degrees From Direction of Fire.

Figure 4. Typical Ground Cover.

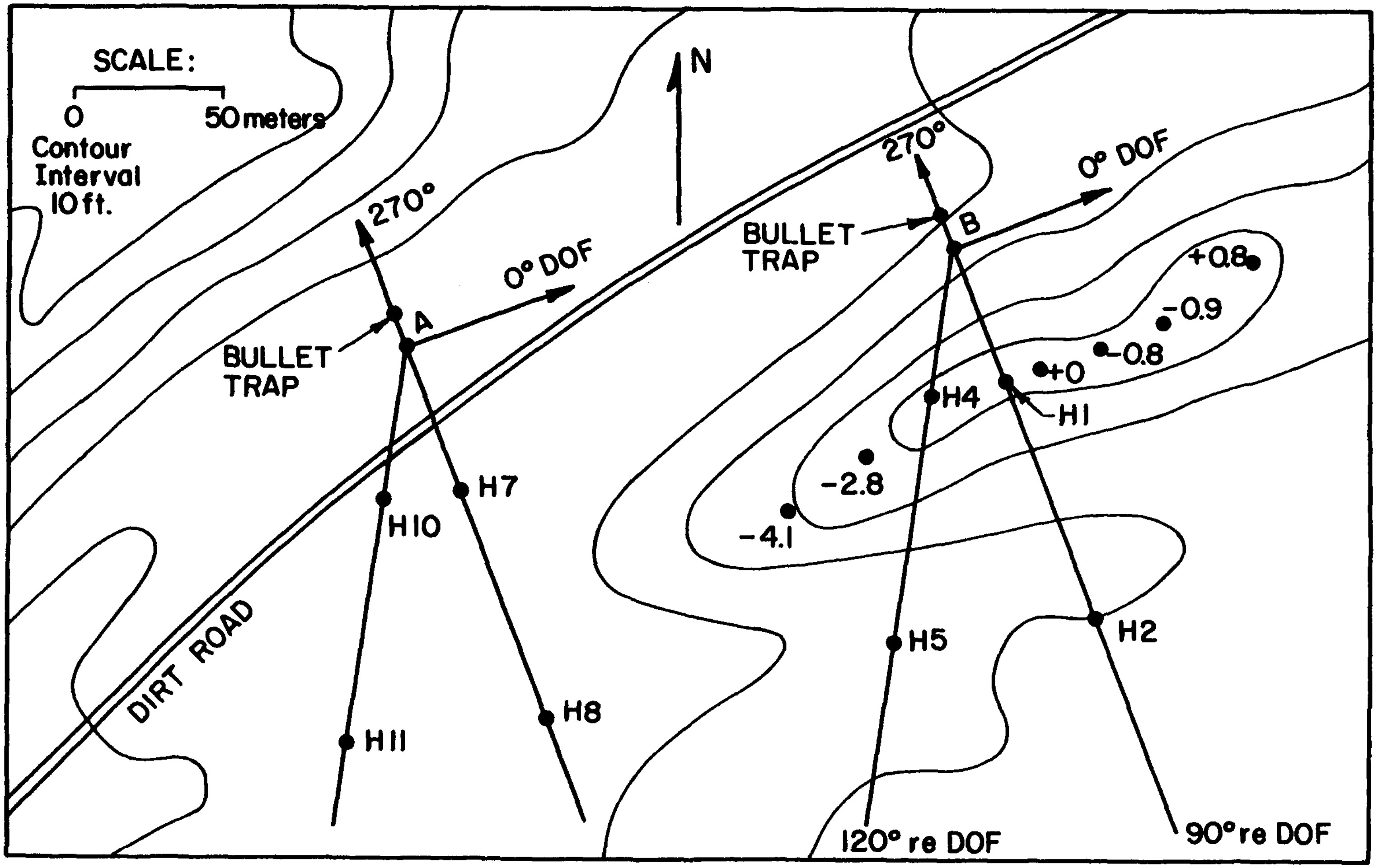


Figure 5. High Berm Experimental Layout and Microphone Array.

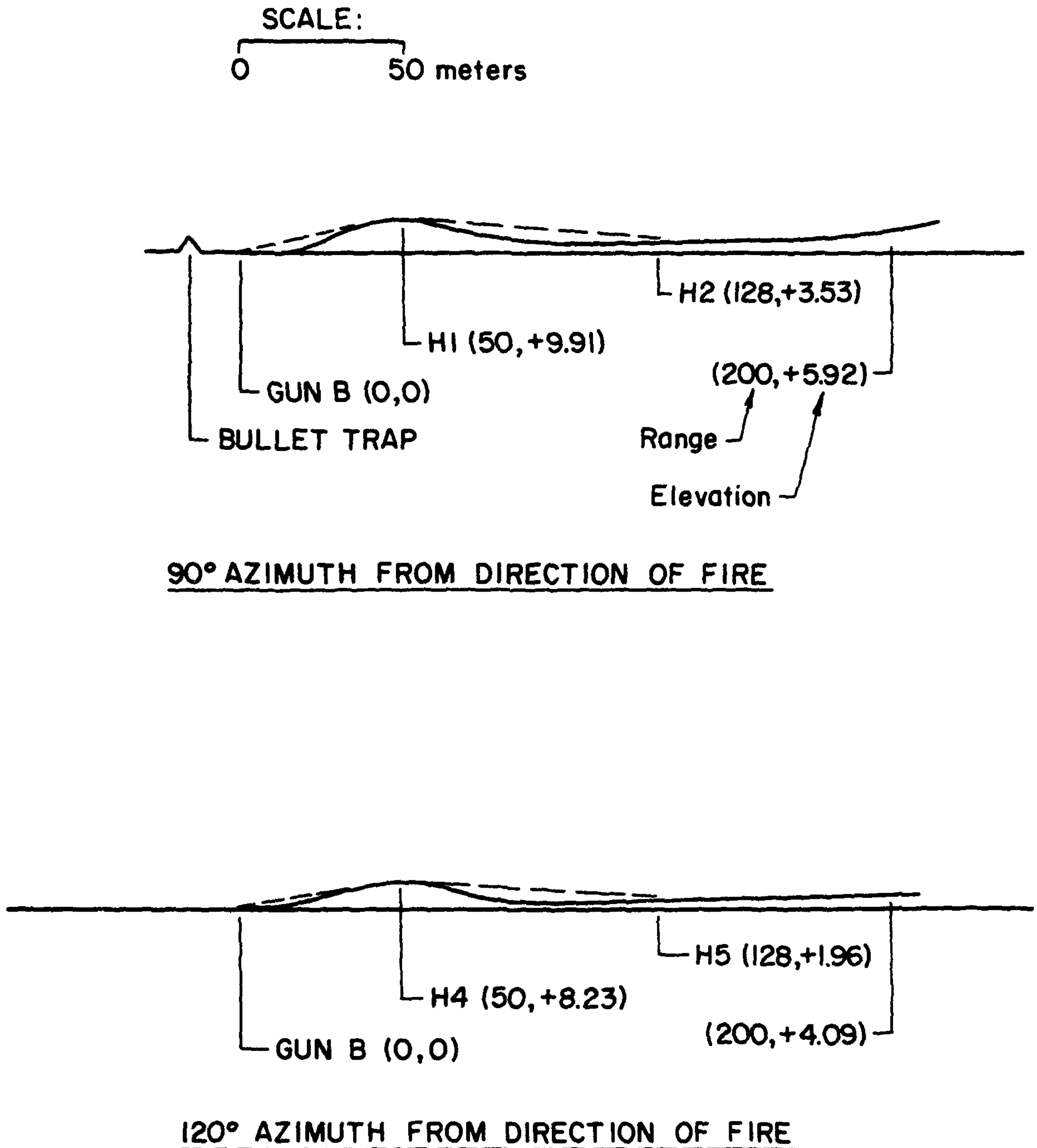


Figure 6. Cross-Section of High Berm.

Figure 7. M2 Machine Gun on Tripod Gun Mount.

Figure 8. M2 Machine Gun Mounted on Ring Mount on M548 Cargo Carrier.

Figure 9. Ground-Effect Experiment Setup at Station H8.

3 INSTRUMENTATION

Figure 10 shows the instrumentation used to measure and record the sound level at each microphone location. The condenser microphones were located 1.3 m above the ground surface (except for the two extra mics at station H8 during the ground effect experiment). The noise events were recorded on digital audio tape for later detailed analysis. Sound level meters were used to measure the sound level at selected mic locations during the experiments; the values were recorded by hand for field examination of data validity and for later comparison with the results of the data reduction. A pistonphone calibration was recorded on tape before and after each experiment to provide a reference during later data reduction. A pistonphone was also used to check the system calibration each time a system was moved or disturbed and at intervals during an extended experiment.

A somewhat different system, using piezoresistive microphones (Figure 11), was used for mic locations L1 and L2 for some of the low berm measurements because the sound level at these locations was sometimes above the range of the condenser microphone systems.

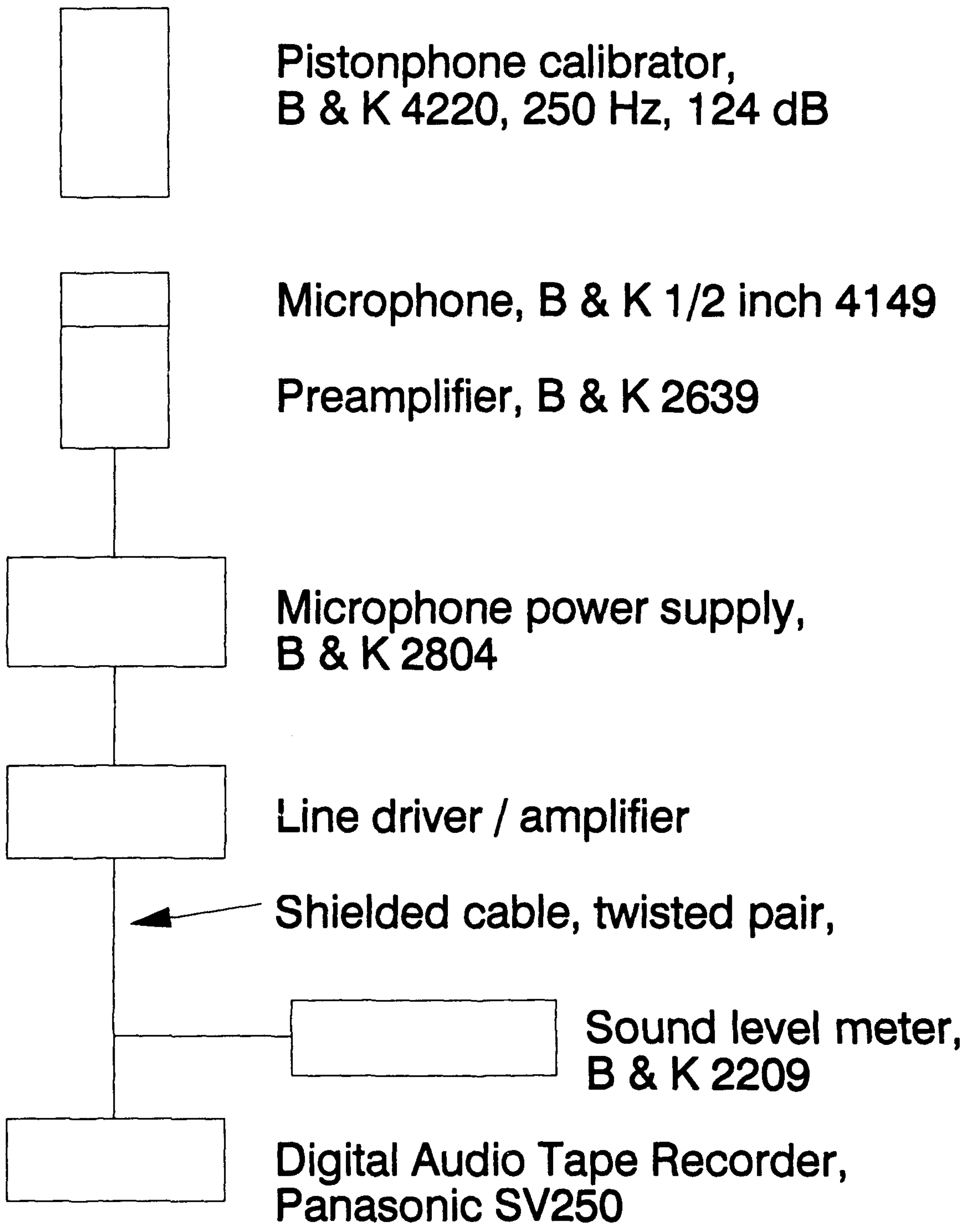


Figure 10. Condenser Microphone Instrumentation System.

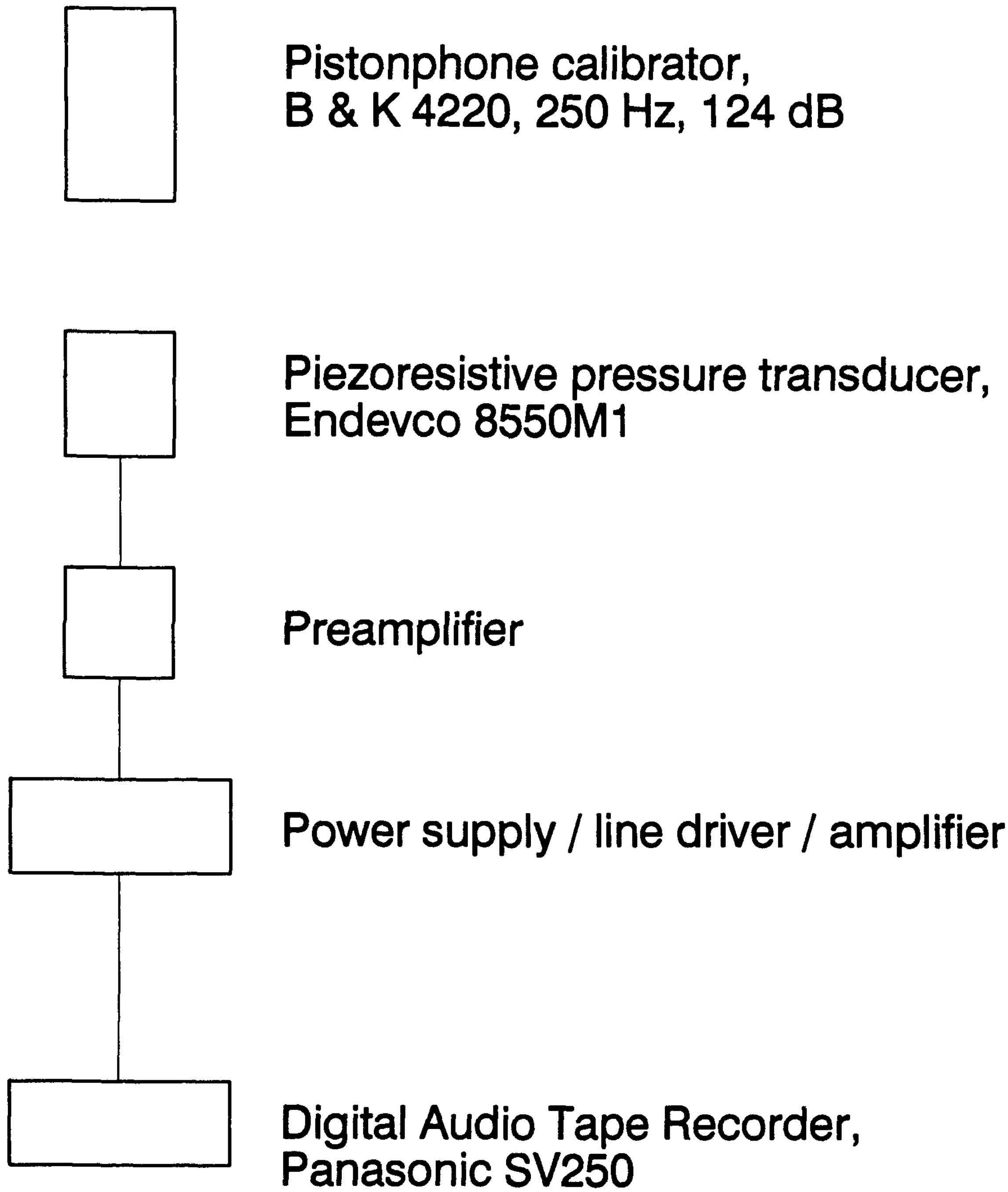


Figure 11. Piezoresistive Microphone Instrumentation System.

4 DATA REDUCTION

The sound level metrics used were peak flat sound pressure level, A-weighted sound exposure level (ASEL) and flat (unweighted) sound exposure level (FSEL), with 20 micropascals as the reference for sound pressure level (ANSI S1.4-1983). Sound exposure is defined as the time integral of the squared pressure.

Figure 12 shows the data reduction system. The digitizing transient waveform analyzer (TWA) was remotely controlled by a custom computer program via an IEEE488 interface. Sound pressure level values were measured by playback of the digital audio tape (DAT) recorded waveform into the TWA, where the waveform was captured and digitized. Typical capture parameters were sample interval 5 microseconds and 4K samples, for a time window length of about 20 milliseconds, which was longer than the duration of any of the events recorded. A-weighting was obtained by passing the signal through an appropriate filter before entry into the TWA. Utilities built into the TWA were used to extract the peak value and also to calculate sound exposures by squaring and integrating the digitized records (flat and A-weighted). The resulting values were sent via the 488 bus to the computer where the level was computed for each event. The recorded pistonphone signal for each microphone was used as the reference level for calculation of sound levels. The computer program also calculated mean levels for each block of data. All calculation of average sound levels was done on an energy basis, that is, pressure squared values were averaged.

The same data reduction system was used to obtain spectra. An FFT (fast Fourier transform) algorithm built in to the TWA was used to obtain a narrow band power spectrum for a specific digitized transient waveform record. The resulting narrow band spectrum digital file was transmitted via the 488 bus to the computer, where it was transformed into an approximate 1/3 octave spectrum by appropriately adding the narrow band power values by a commercial spreadsheet program (ANSI S1.6-1967). Typical parameter values used were a sample interval of 20 microseconds (50 kilohertz sample rate) and 16K samples, which resulted in a time window length of 0.384 seconds, yielding a narrow band power spectrum bandwidth of about 3 Hertz and a reliable upper frequency limit of 25 KHz. This is an adequate range since human response requires consideration of frequencies only from 20 Hz up to about 20 KHz. The narrow band spectrum bandwidth of about 3 Hz allowed quite accurate 1/3 octave band power values even for the 31.5 Hz (28 to 35.5 Hz) band.

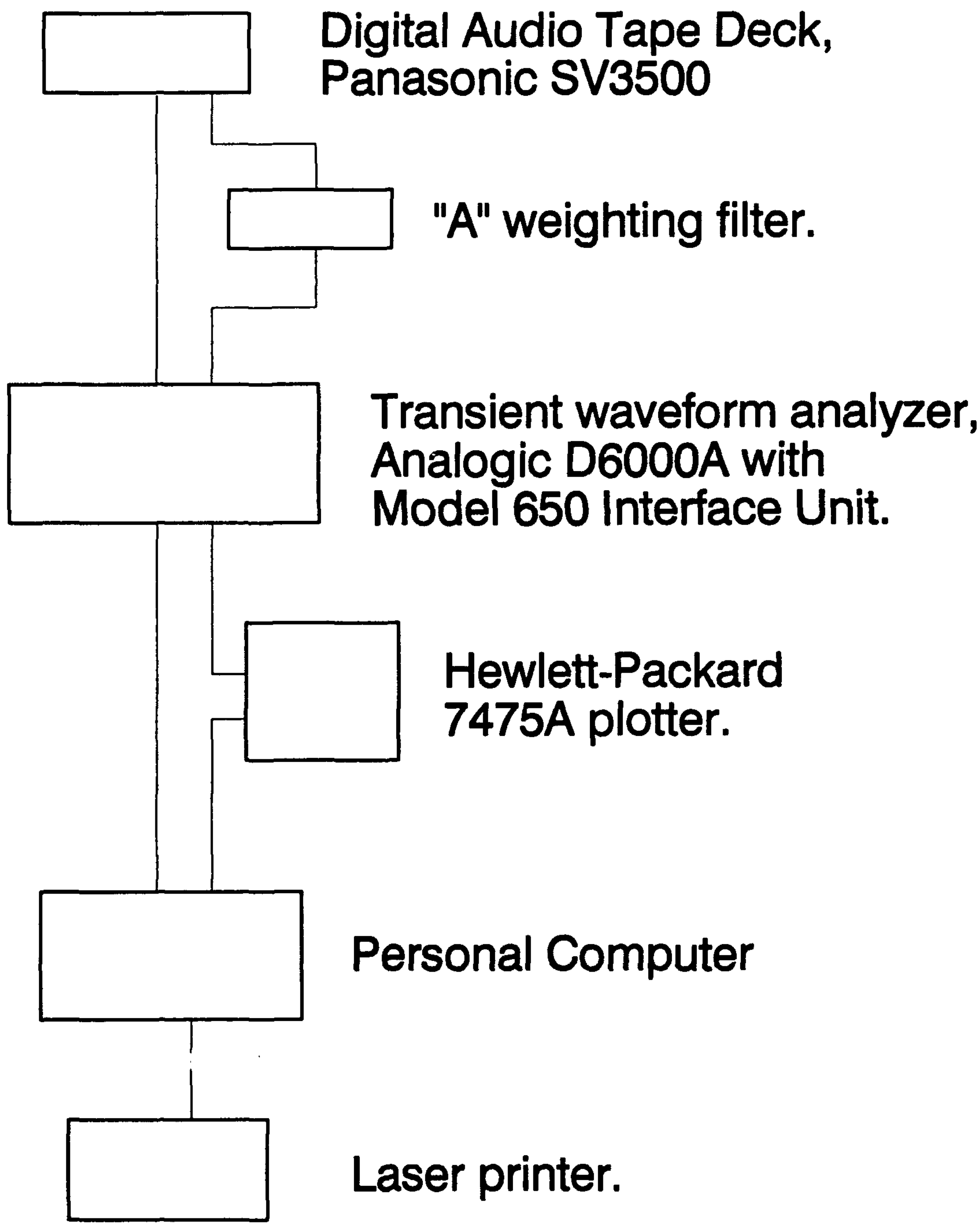


Figure 12. Data Reduction System.

5 GROUND EFFECT EXPERIMENTAL RESULTS

Sound level attenuates (decreases) with distance from the sound source due to geometrical spreading, for example, spherical spreading from a point source. Attenuation also occurs due to absorption of sound wave energy by the propagation medium, which in this case is the atmosphere. Additional attenuation occurs due to the proximity of the sound propagation path to the ground surface. This attenuation is often referred to as "excess ground attenuation" and is actually due to several phenomena. One cause is the variation of temperature and wind speed in the boundary layer near the surface, both of which affect propagation speed and thus can cause refraction of sound energy toward or away from the boundary, resulting in an increase or decrease in the received sound level. Both the temperature and wind profiles can depend strongly on solar radiation and on the radiation absorptivity of the ground. Another cause is wave interference between the direct path and ground-reflected sound path. Still another is dissipation of wave energy by the ground. These last two contributions cannot be readily assessed separately; their relative importance depends on many details of the configuration. The frequency-dependent magnitude of attenuation is a function of the height of the propagation path and of the character of the ground surface.

Measurements were made to characterize the excess ground attenuation at the experimental site. As described previously, different path heights were achieved by means of three microphone heights and two gun muzzle heights above the ground surface. The ground surface was generally flat and level. The soil was quite sandy and covered by a fairly dense cover of weeds and small bushes. Figure 13 shows typical spectral results. These data show a typical notch in the vicinity of 250 Hz. Attenuation at higher frequencies is strongly dependent on path height, with the difference for the highest and lowest paths amounting to as much as 30 dB. The effect of path height at low frequencies is relatively much smaller. These spectral plots yield an important insight into the effect of frequency weighting on the measured broadband sound level. The unweighted low frequency energy exceeds the higher frequency energy by at least 10 dB for all but the highest path. This means that the "flat-weighted" overall sound level for these paths will be little affected by the excess ground attenuation of the high frequencies. On the other hand, "A-weighting," which is used to simulate human auditory frequency response, strongly discriminates against the low frequencies (for example, -26.2 dB at 63 Hz) and gives greatest emphasis to frequencies in the vicinity of 1 KHz (ANSI S1.4-1983). Consequently the overall A-weighted sound level of the data examples in Figure 13 are very strongly affected by the excess ground attenuation. An examination of the ASEL and FSEL data (Figures 14 and 15) shows this. This effect will be clearly discernable in the insertion loss data presented below.

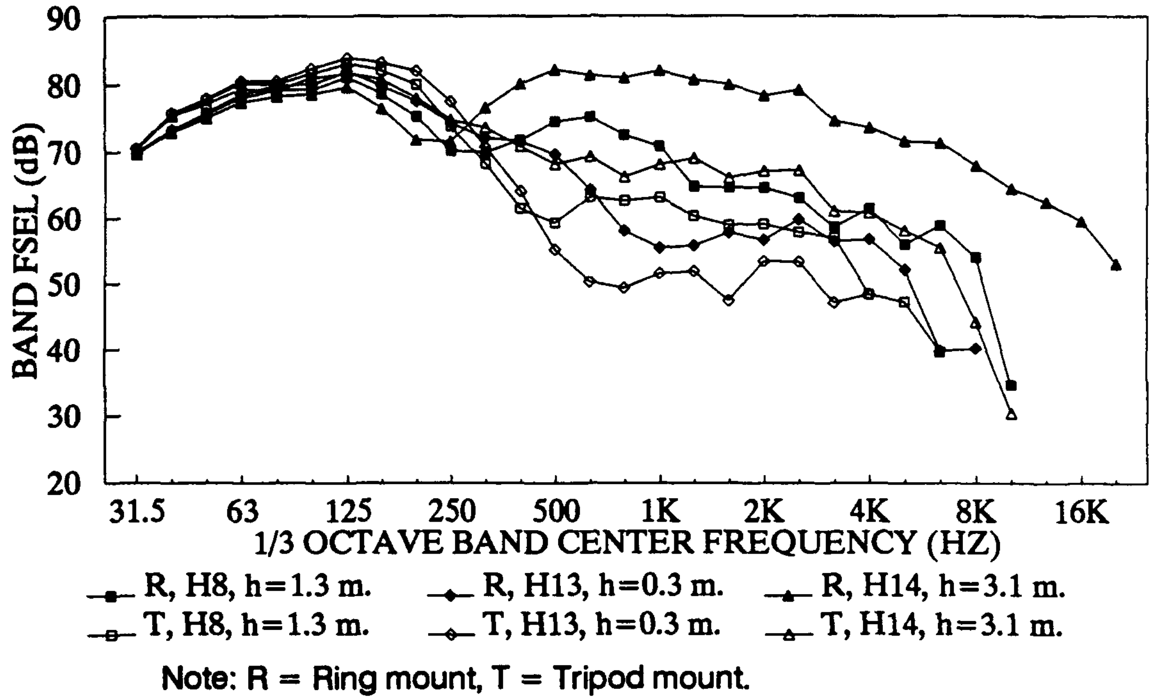
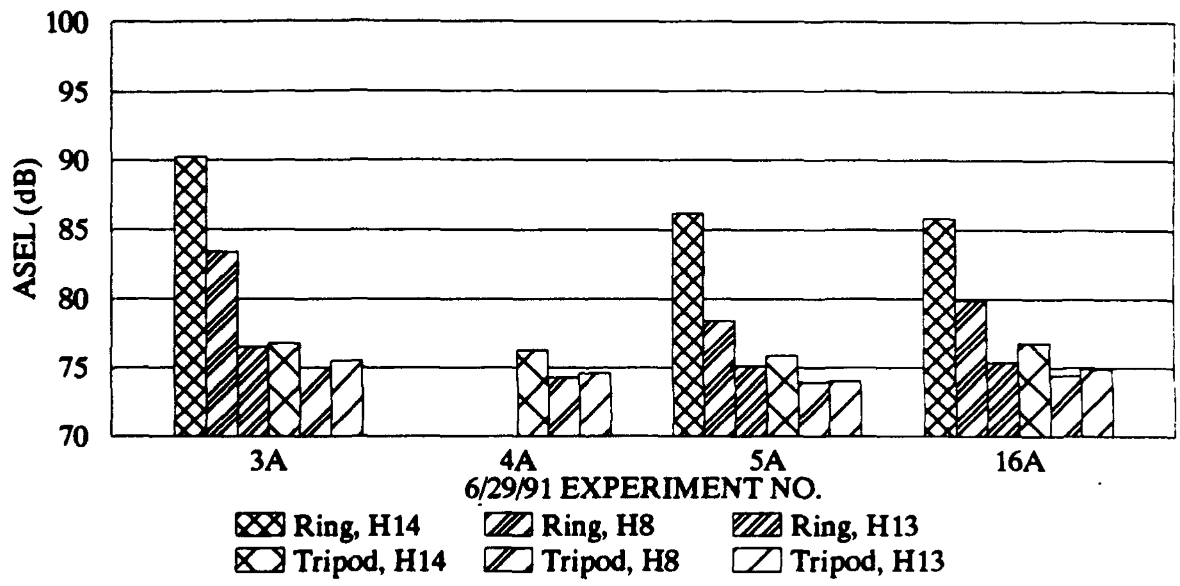
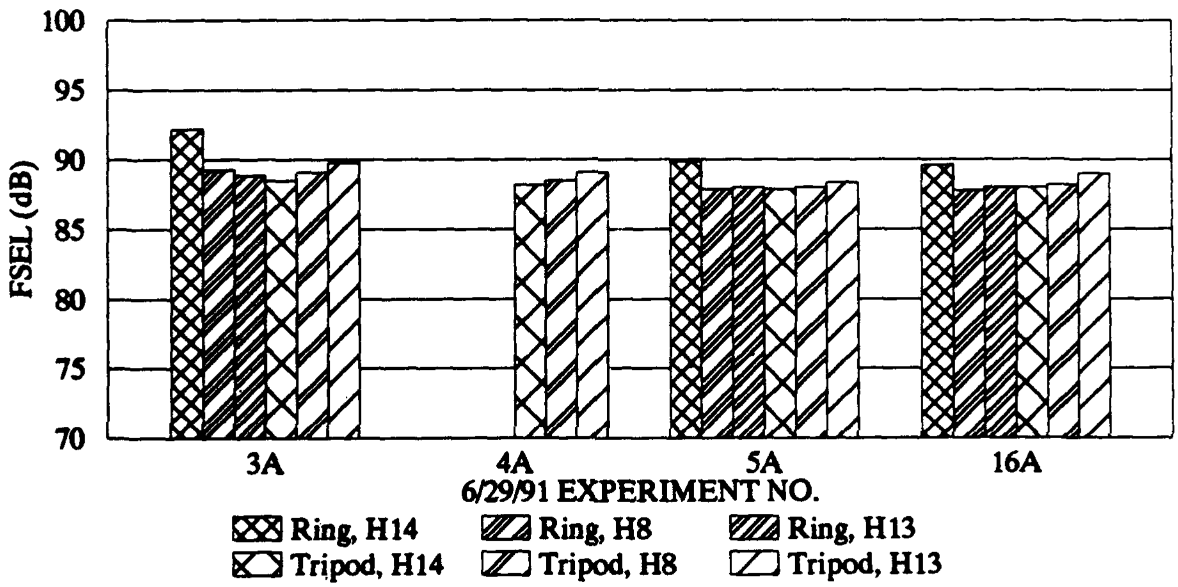


Figure 13. **Effect of Propagation Path Height on FSEL Spectrum for Propagation Over Level Sandy Ground at Camp Grayling, MI (6/29/91, Experiment 3A).**



Experiment number:	3A	4A	5A	16A
Wind direction re. DOF:	70°	70°	70°	150°
Wind speed (m/sec):	0–2	0–3	0–4	2–4

Figure 14. Effect of Source Height and Receiver Height on ASEL at 128 m From Source.



Experiment number:	3A	4A	5A	16A
Wind direction re. DOF:	70°	70°	70°	150°
Wind speed (m/sec):*	0–2	0–3	0–4	2–4

Figure 15. Effect of Source Height and Receiver Height on FSEL at 128 m From Source.

6 INSERTION LOSS RESULTS

Calculations

Insertion loss calculations were carried out for the combinations of relative locations and heights of barrier, source, and receiver used to obtain experimental data. The calculation procedure is based on the FHA (Federal Highway Administration) algorithm (FHA 1982), described in detail in previous publications (Pater 1992). The algorithm was developed for thin sharp-edged barriers and so could be expected to yield only approximately correct results for the berms of the present experiments (cf. Figures 3 and 6). Previous studies (Pater 1992, 1993) concluded that the algorithm gives useful results when the direction of fire is perpendicular to the barrier, provided that propagation effects, particularly excess ground attenuation, are accounted for. However, the algorithm was judged to be less useful when the direction of fire is parallel to the barrier. This is thought to be a consequence of the inability of the simple algorithm to properly account for the effects of the asymmetrical directivity of the gun muzzle blast acoustic field.

The calculation algorithm requires that the source spectrum at the barrier edge be known. The calculations were carried out using the octave band relative spectrum (Figure 16). This spectrum was derived from experimental spectral data for microphone location L2 (at the top of the low berm, 7 m behind the "B" gun) approximately corrected for excess ground attenuation (Embleton 1982). Table 4 summarizes the calculated insertion loss results, which are later compared with the experimental results. Note that the calculated A-weighted insertion loss is larger than the flat weighted insertion loss. Pater (1992) details the following process. Diffraction around the edge of a barrier attenuates higher frequency waves more strongly than lower frequency waves. A-weighting more strongly attenuates the lower frequencies, yielding a larger insertion loss for spectra with significant low frequency energy.

High Berm, Ring Mount Gun, DOF Parallel to Berm

Figure 17 shows experimental spectra for several microphone locations for the high berm and the ring mount gun case (muzzle height 3.15 m). The microphone array was described in detail earlier. Microphone H1 was located on the top of the berm and mic H7 is the corresponding location (90 degree, 50 m) for the unshielded gun. The spectra at these two locations show some differences, probably a consequence of source directivity and the differing propagation path height and other path characteristics. Mic H2 (90 degree, 128 m) is shielded by the berm, and mic H8 is the corresponding unshielded location. The spectrum for mic H2 lies well below that of mic H8, and the difference between the levels of the two spectra is generally larger for higher frequencies, which is the expected effect of diffraction around the berm. One might expect the difference to be greater, except for excess ground attenuation effects, which could be expected to diminish the higher frequency energy of the unshielded path more than that of the shielded path because of the lower path height (Figure 13).

Figure 18 shows calculated and experimental broadband insertion loss data for the high gun and high berm combination in terms of ASEL, and in terms of additional noise parameters in the tables included in Appendix A. Note that the calculated insertion loss at 90-degree azimuth is about 30 dB; in practice, insertion loss of more than about 24 dB is seldom achieved because of scattering and refraction (Beranek 1971, p 174-180; FHA 1982). The achieved insertion loss varied from day to day, probably because of different wind conditions. Note that data were obtained for upwind, downwind, and both crosswind directions relative to the path from source to receiver. There appears to be no obvious or simple systematic explanation for the variation of insertion loss with wind direction.

The measured insertion loss amounts roughly to 15 to 25 dB for the 90-degree azimuth and 10 to more than 20 dB for 120-degree azimuth. These are significant noise level reductions, since a reduction in noise level of 10 dB is generally perceived as a change in subjective loudness by a factor of two.

High Berm, Tripod Gun Mount, DOF Parallel to Berm

Figure 19 shows ASEL insertion loss results for the low (tripod mount) gun height and high berm combination. Table 4 and the tables of Appendix A show values in terms of other noise metrics. The experimental ASEL insertion loss amounts to about 9 to 16 dB, which is a significant noise reduction. The experimental insertion loss values are, however, considerably smaller than the calculated values. Recall that previous studies showed that the algorithm used does not yield accurate insertion loss predictions for the case when the barrier is parallel to the direction of fire.

A comparison of Figures 18 and 19 shows that the calculated insertion loss values for the two different gun mount muzzle heights are about the same at 30 dB for the 90-degree azimuth, and are different by only about 3 dB for the 120-degree azimuth. One might have expected that the calculated insertion loss would be substantially larger for the low gun, since the net barrier height H (Table 4) is much larger. However, insertion loss varies logarithmically with barrier height, and the barrier is tall enough that the difference in net height is relatively unimportant.

The comparison of Figures 18 and 19 also shows, somewhat surprisingly, that the experimental values of insertion loss for the low gun are substantially *smaller* than for the higher gun. Examining the spectra of Figure 20 (low gun) and comparing them with the spectra of Figure 17 (high gun) reveals that the values of band sound level at 31.5 Hz are essentially the same for the two guns. The attenuation of higher frequencies for mic H8 is much larger for the low gun, most probably the result of excess ground attenuation for the lower propagation path. This results in smaller insertion loss for the low gun. This is shown more clearly in Table 5, which summarizes the measured ASEL values for mics H2 and H8 for all of the high berm insertion loss experiments. Note that, for direction of fire parallel to the berm, the noise level at the shielded mic (H2) did not vary a great deal for the several experiments carried out on different days for the two guns under somewhat different propagation conditions. Larger variation occurred for the unshielded mic (H8). Careful examination of experimental conditions indicate the difference is most probably due to differences in excess ground attenuation associated with the different propagation path height for the two guns mounts.

These results suggest noise mitigation strategies. Even where a berm or other noise barrier is not available, lower noise levels can still be achieved by using the lower gun mount. A barrier such as the one used in this study offers considerable additional noise reduction. If a berm is available to shield receivers from the muzzle blast noise, the current data indicate similar noise levels for both gun mount types.

High Berm, Tripod Gun Mount, DOF Normal to Berm

Figure 21 shows calculated and experimental insertion loss results for the tripod mounted gun firing crossrange, for which the berm is located behind the gun and perpendicular to the direction of fire. The calculated A-weighted insertion loss amounts to about 22 dB directly to the rear. The measured insertion loss is considerably less, at about 10 dB directly to the rear. For the 120-degree azimuth, along which the berm height is somewhat less (Table 3) and where source directivity also plays a role, the insertion loss is somewhat less. These measured insertion loss values are not greatly different from those for the barrier parallel to the direction of fire.

Table 4

Calculated Insertion Loss Values for the .50 Caliber Machine Gun Experiments at Camp Grayling

Azimuth (deg)	Range (m)	Gun Mount Type	Gun Height (m)	Berm Height (m)	H (m)	Insertion Loss (dB) FSEL	Insertion Loss (dB) ASEL
Case: low berm, tripod mount, DOF downrange; barrier axis normal to direction of fire							
180.0	150	Tripod	0.33	3.0	2.67	12.7	16.7
177.5	161	Tripod	0.33	3.0	2.67	12.6	16.7
208.1	279	Tripod	0.33	3.0	2.67	12.2	16.1
240.0	80	Tripod	0.33	3.0	2.67	11.2	14.9
Case: high berm, tripod mount, DOF crossrange; barrier axis normal to direction of fire							
180.0	128	Tripod	0.33	9.91	9.58	17.1	21.5
210.0	128	Tripod	0.33	8.23	7.9	15.5	19.9
Case: high berm, both mounts, DOF downrange; barrier axis parallel to direction of fire							
90.0	128	Tripod	0.33	9.91	9.58	25.4	29.9
120.0	128	Tripod	0.33	8.23	7.9	16.7	21.1
90.0	128	Ring	3.15	9.91	6.76	25.3	29.8
120.0	128	Ring	3.15	8.23	5.08	13.5	17.6

Table 5 gives noise level ASEL values for the crossrange firing direction as well as the downrange. Note that the crossrange firing direction noise values are lower than downrange values; this is a result of muzzle blast directivity, not of insertion loss or excess ground attenuation. This illustrates the fact that sometimes noise levels at specific receivers can be reduced by changing the direction of fire. In general, for guns not equipped with a muzzle device such as a muzzle brake, the muzzle blast noise level is significantly lower behind the gun than in front or to the side (Pater 1992, 1981).

Low Berm, Tripod Gun Mount, DOF Normal to Berm

Figure 22 shows the A-weighted insertion loss values for the low (about 3-m height) berm. The calculated insertion loss at the 180-degree azimuth is about 5 dB smaller than for the higher berm for the same tripod gun mount. The achieved ASEL insertion loss was about 5 to 10 dB, depending on propagation conditions, which is again substantially lower than the calculated value.

Table 5

Measured ASEL (dB) Noise Levels for the .50 Caliber Machine Gun Noise-Shielding Experiments

Date	Experiment	Mic H2 (dB)	Mic H8 (dB)	Insertion Loss (dB)
Case: high berm, ring mount, DOF downrange; barrier axis parallel to direction of fire				
6/11	11B, 12A	64.4	88.8	24.4
6/12	6A, 7B	64.9	87.0	22.1
6/13	2B, 3A	63.0	79.2	16.2
6/13	2B, 4A	63.0	81.1	18.1
6/29	8A, 8B	62.3	78.2	15.9
Case: high berm, tripod mount, DOF downrange; barrier axis parallel to direction of fire				
6/11	3B, 3A	63.5	75.0	11.5
6/13	5A,4B	63.2	75.1	11.9
6/29	9A,9B	62.7	78.8	16.1
Case: high berm, tripod mount, DOF crossrange; barrier axis normal to direction of fire				
6/11	7	58.4	69.0	10.6
6/29	10	58.0	69.4	11.4

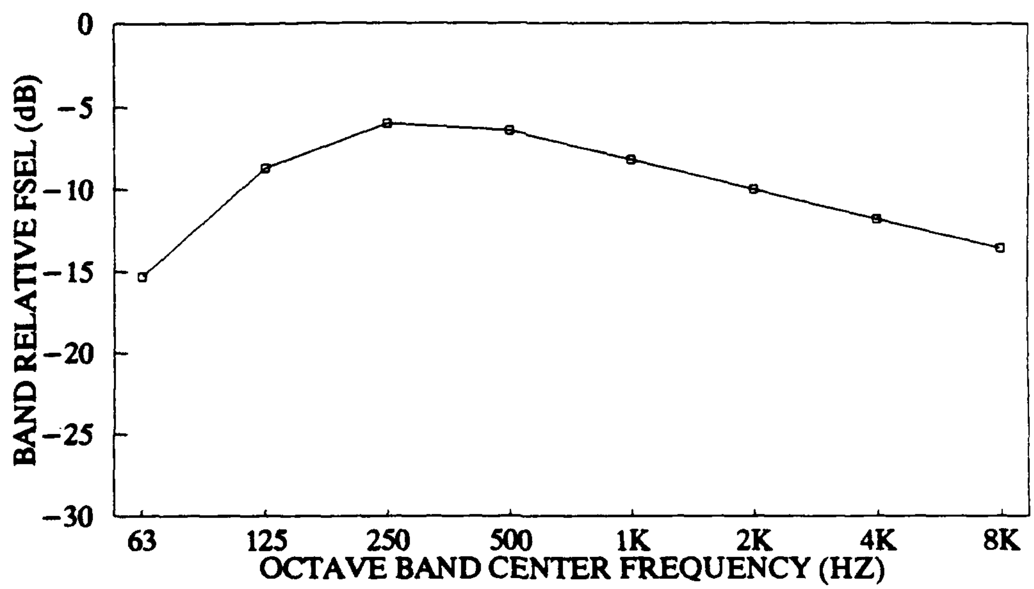


Figure 16. Source Spectrum Used for Insertion Loss Calculations.

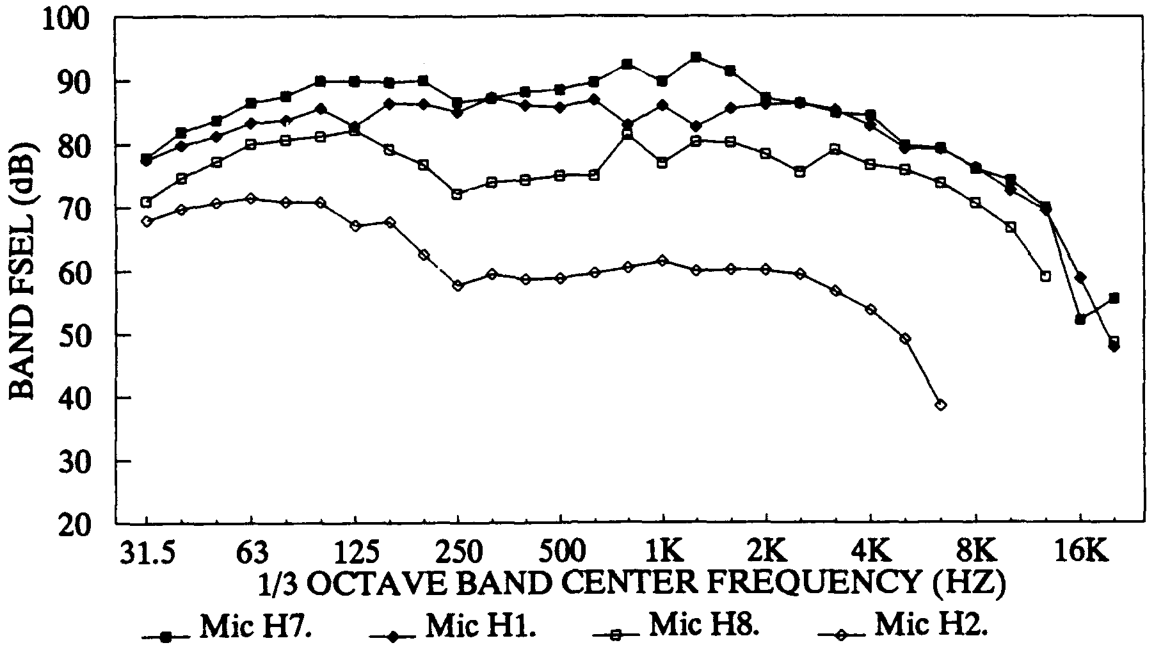
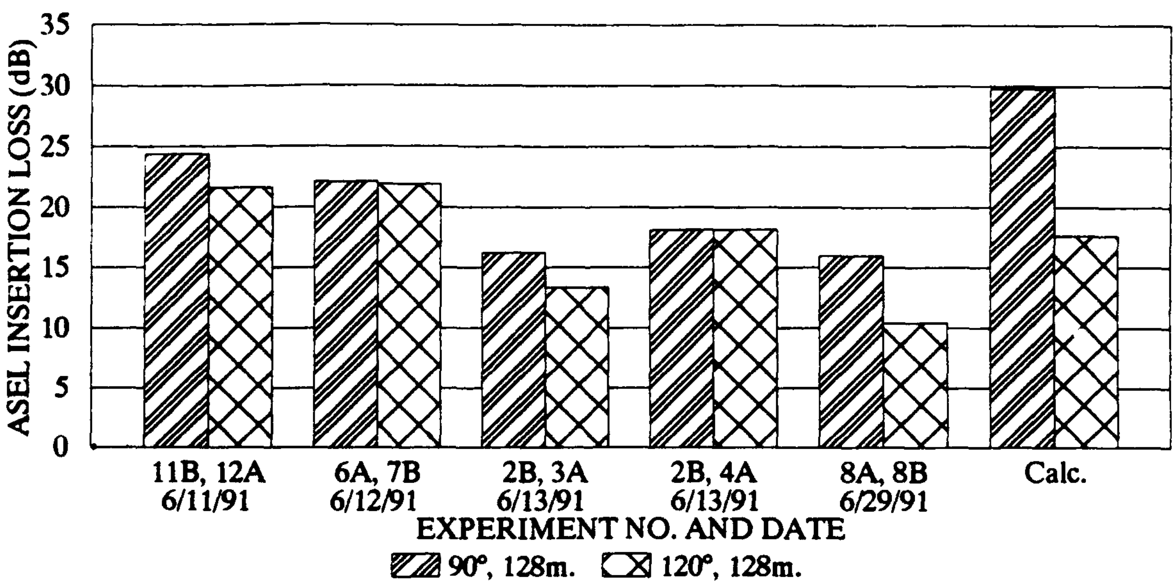
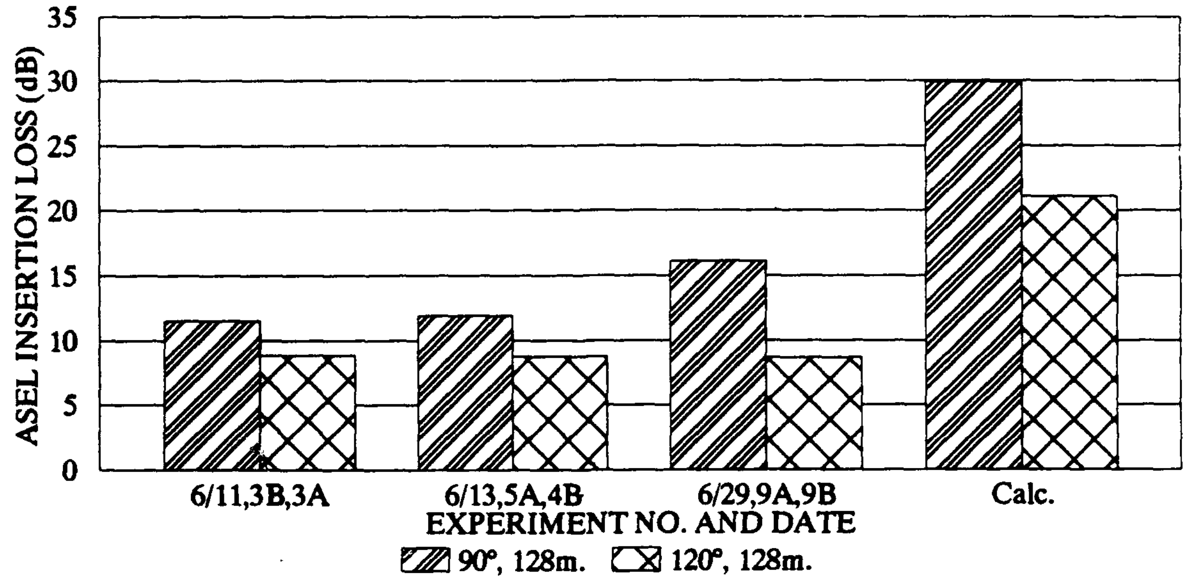


Figure 17. Combined Effect of Distance, Barrier, and Excess Attenuation on FSEL Spectrum for High Berm, High Gun (h=3.15m, 6/12/91, Experiments 6A and 7B).



Experiment number:	11B, 12A	6A, 7B	2B, 3A	2B, 4A	8A, 8B
Experiment date:	6/11	6/12	6/13	6/13	6/29
Wind direction re. DOF:	270°	0°	90°	90°	150°
Wind speed (m/sec):	2–4	4–7	2–4	2–4	2–4

Figure 18. Measured Insertion Loss for the High Berm, Ring Mount Gun (Barrier Axis Parallel to Gun Direction of Fire).



Experiment number:	3B, 3A	5A, 4B	9A, 9B
Experiment date:	6/11	6/13	6/29
Wind direction re. DOF:	180°	90°	150°
Wind speed (m/sec):	0–2	2–4	1–4

Figure 19. Measured Insertion Loss for the High Berm, Tripod Mount Gun Firing Downrange (Berm Axis Parallel to the Gun Direction of Fire).

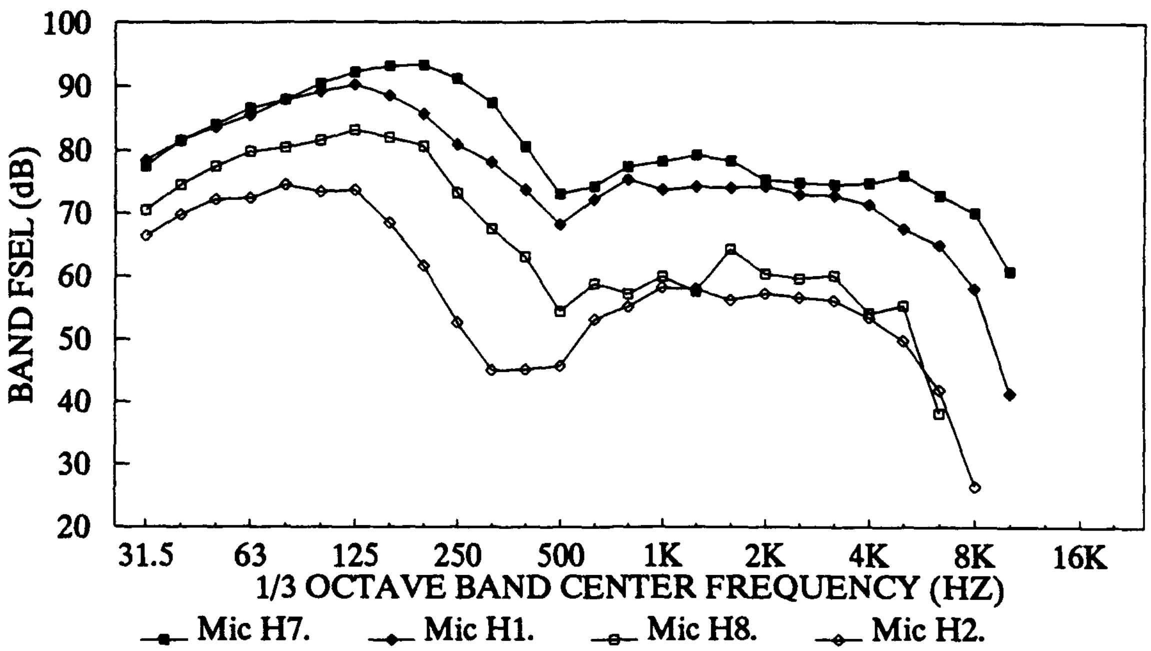
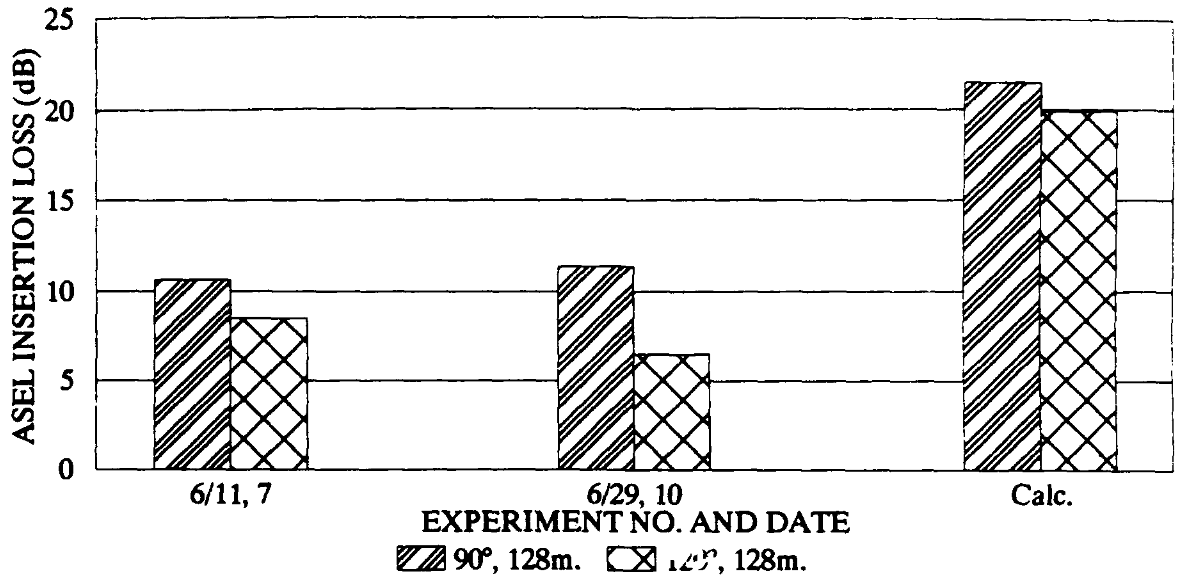
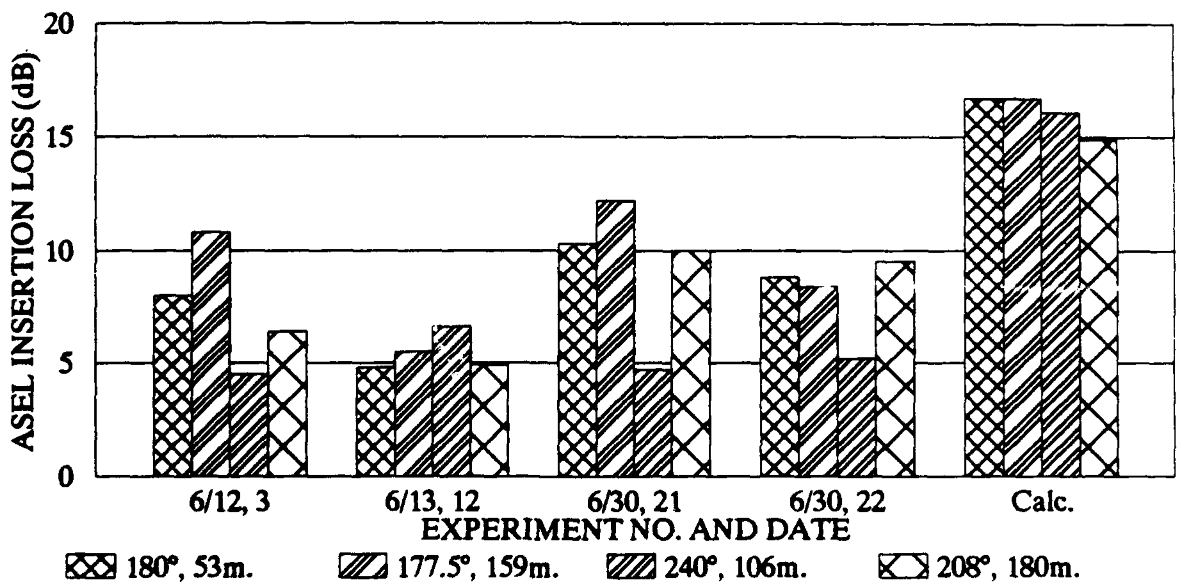


Figure 20. Combined Effect of Distance, Barrier, and Excess Attenuation on FSEL Spectrum for the High Berm, Low Gun, Zero Degrees DOF (h=0.33m, 6/29/91, Experiment 9).



Experiment number:	7	10
Experiment date:	6/11	6/29
Wind direction re. DOF:	180°	150°
Wind speed (m/sec):	0–2	1–4

Figure 21. Measured Insertion Loss for the High Berm, Tripod Mount Gun, Firing Crossrange (Berm Axis Perpendicular to Gun Direction of Fire).



Experiment number:	3	12	21	222
Experiment date:	6/12	6/13	6/30	6/30
Wind direction re. DOF:	280°	90°	45°	45°
Wind speed (m/sec):	2–4	2–4	1–3	3

Figure 22. Measured Insertion Loss for the Low Berm, Tripod Mount Gun Firing Downrange (Berm Axis Perpendicular to the Direction of Fire).

7 CONCLUSIONS

Berms and ridges can yield significant reduction of .50 caliber machine gun noise. As was expected, propagation conditions, particularly wind speed and direction, can have a significant effect on achieved barrier insertion loss. Also as expected, higher berms generally yield more noise reduction than lower berms. A 3-m high berm yielded about 5 to 10 dB reduction in ASEL directly to the rear, while a roughly 10 m high berm yielded from about 10 to over 20 dB reduction. For the higher berm, noise reduction was greater for the high (ring mount) gun than for the tripod gun, even though the effective barrier height is smaller for the high gun and thus should be expected to yield larger insertion loss. The explanation lies in the excess ground attenuation, which was much larger for the low gun (tripod mount).

Excess ground attenuation causes greater attenuation for sound propagation paths that are closer to the ground. The effect is particularly pronounced for surfaces that are acoustically absorbent, such as sandy or grass-covered soils. If a berm or other noise barrier is not present, lower noise levels can thus be achieved by using the lower gun mount. A barrier such as was used in the present investigation offers considerable additional noise reduction. If a berm is available to shield receivers from the muzzle blast noise, the current data indicate similar noise levels for both gun mount types, even though the *reduction* in noise level is larger for the higher gun.

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APPENDIX:

Experimental Data

Table A1. List of Appendix A Data Tables.

TABLE	EXPT.	BERM	GUN MOUNT	DOF (DEG)	WIND re. DOF (DEG)	WIND SPEED (M/S)	DATA TYPE
A2	6/11, 3B, 3A	High	T	0	180	0−2	Insertion Loss
A3	6/11, 3B, 4B	High	T	0	180	0−2	Propagation
A4	6/11, 7	High	T	270	180	0−2	Insertion Loss
A5	6/11, 11B, 12A	High	R	0	270	2−4	Insertion Loss
A6	6/11, 11B, 12B	High	R	0	270	2−4	Propagation
A7	6/12, 3	Low	T	0	280	2−4	Insertion Loss
A8	6/12, 6A, 7B	High	R	0	0	4−7	Insertion Loss
A9	6/12, 6A, 7B	High	R	0	250,0	4−7	Propagation
A10	6/13, 2B, 3A	High	R	0	90	2−4	Insertion Loss
A11	6/13, 2B. 4A	High	R	0	90	2−4	Insertion Loss
A12	6/13, 3A, 4A	High	R	0	90	2−4	Propagation
A13	6/13, 5A, 4B	High	T	0	90	2−4	Insertion Loss
A14	6/13, 12	Low	T	0	90	2−4	Insertion Loss
A15	6/29, 3A	None	Both	0	70	0−2	Path height
A16	6/29, 4A	None	T	0	70	0−3	Path height
A17	6/29, 5A	None	Both	0	70	0−4	Path height
A18	6/29, 8A, 8B	High	R	0	150	2−4	Insertion Loss
A19	6/29, 9A,9B	High	T	0	150	1−4	Insertion Loss
A20	6/29, 10	High	T	270	150	1−4	Insertion Loss
A21	6/29, 15A	None	T	0	150	1−4	Gun comparison
A22	6/29, 16A	None	Both	0	150	2−4	Path height
A23	6/30, 21	Low	T	0	45	1−3	Insertion Loss
A24	6/30, 22	Low	T	0	45	3	Insertion Loss

Table A2.

EXPT:	Camp Grayling, 50 caliber	Range 35 (High berm).
DATE:	6-11-91 Experiments 3B,3A.	
GUN @:	Tripod mount, DOF 0°. Berm to the side.	
WIND:	180°, 0-2 meters/sec.	

UNSHIELDED GUN Expt. 3A

****

Mic #	Angle (deg)	Distance (m)	Flatpeak (dB)	Apeak (dB)	ASEL (dB)	FSEL (dB)
7	90.0	50.0	127.2	124.7	90.5	99.7
8	90.0	128.0	114.5	106.8	75.0	89.1
10	120.0	50.0	124.1	120.6	87.6	96.2
11	120.0	128.0	111.6	101.7	72.3	85.4

SHIELDED GUN Expt. 3B

****

Mic #	Angle (deg)	Distance (m)	Flatpeak (dB)	Apeak (dB)	ASEL (dB)	FSEL (dB)
1	90.0	50.0	124.8	123.4	87.2	97.4
2	90.0	128.0	105.3	87.3	63.5	82.0
4	120.0	50.0	118.7	112.2	82.6	93.0
5	120.0	128.0	102.3	90.9	63.4	78.5

INSERTION LOSS

****

Angle (deg)	Distance (m)	Flatpeak (dB)	Apeak (dB)	ASEL (dB)	FSEL (dB)
90.0	50.0	2.4	1.3	3.3	2.3
90.0	128.0	9.2	19.5	11.5	7.1
120.0	50.0	5.4	8.4	5.0	3.2
120.0	128.0	9.3	10.8	8.9	6.9

Table A3.

EXPT:	Camp Grayling, 50 caliber Range 35 (High berm).
DATE:	6–11–91 Expts 3B,4B for comparison of propagation conditions.
GUN @:	Tripod mount, DOF 0°. Berm to the side.
WIND:	180°, 0–2 meters/sec.

SHIELDED GUN Expt. 3B

****

Mic #	Angle (deg)	Distance (m)	Flatpeak (dB)	Apeak (dB)	ASEL (dB)	FSEL (dB)
1	90.0	50.0	124.8	123.4	87.2	97.4
2	90.0	128.0	105.3	87.3	63.5	82.0
4	120.0	50.0	118.7	112.2	82.6	93.0
5	120.0	128.0	102.3	90.9	63.4	78.5

SHIELDED GUN Expt. 4B

****

Mic #	Angle (deg)	Distance (m)	Flatpeak (dB)	Apeak (dB)	ASEL (dB)	FSEL (dB)
1	90.0	50.0	124.9	123.5	87.3	97.2
2	90.0	128.0	105.6	87.5	63.6	82.0
4	120.0	50.0	119.1	113.8	83.3	93.0
5	120.0	128.0	102.0	90.8	62.9	78.1

CHANGE IN CONDITIONS

****

Angle (deg)	Distance (m)	Flatpeak (dB)	Apeak (dB)	ASEL (dB)	FSEL (dB)
90.0	50.0	−0.1	−0.1	−0.1	0.2
90.0	128.0	−0.3	−0.2	−0.1	0.0
120.0	50.0	−0.4	−1.6	−0.7	0.0
120.0	128.0	0.3	0.1	0.5	0.4

Table A4.

EXPT:	Camp Grayling, 50 caliber		Range 35 (High berm).
DATE:	6–11–91 Experiment 7.		
GUN @:	Tripod mount, DOF 270°. Berm to the rear.		
WIND:	180°, 0–2 meters/sec.		

UNSHIELDED GUN Expt. 7
****

Mic #	Angle (deg)	Distance (m)	Flatpeak (dB)	Apeak (dB)	ASEL (dB)	FSEL (dB)
7	90.0	50.0	117.8	111.1	84.8	91.8
8	90.0	128.0	107.6	99.5	69.0	81.6
10	120.0	50.0	119.7	113.0	84.6	92.8
11	120.0	128.0	108.7	99.0	70.3	82.5

SHIELDED GUN Expt. 7
****

Mic #	Angle (deg)	Distance (m)	Flatpeak (dB)	Apeak (dB)	ASEL (dB)	FSEL (dB)
1	90.0	50.0	116.9	115.9	82.5	91.6
2	90.0	128.0	97.7	82.4	58.4	75.7
4	120.0	50.0	115.6	110.4	81.3	90.8
5	120.0	128.0	99.6	89.5	61.8	76.4

INSERTION LOSS
****

Angle (deg)	Distance (m)	Flatpeak (dB)	Apeak (dB)	ASEL (dB)	FSEL (dB)
90.0	50.0	0.9	−4.8	2.3	0.2
90.0	128.0	9.9	17.1	10.6	5.9
120.0	50.0	4.1	2.6	3.3	2.0
120.0	128.0	9.1	9.5	8.5	6.1

Table A5.

EXPT:	Camp Grayling, 50 caliber	Range 35 (High berm).
DATE:	6-11-91. Experiments 11B,12A.	
GUN @:	Ring mount, DOF 0°. Berm to the side.	
WIND:	270°, 2-4 meters/sec.	

UNSHIELDED GUN Expt. 12A
****

Mic #	Angle (deg)	Distance (m)	Flatpeak (dB)	Apeak (dB)	ASEL (dB)	FSEL (dB)
7	90.0	50.0	127.6	126.5	94.5	97.8 CLIPPED
8	90.0	128.0	126.2	124.2	88.8	92.0
10	120.0	50.0	126.5	126.2	94.4	97.0 CLIPPED
11	120.0	128.0	122.2	120.5	85.4	87.6

SHIELDED GUN Expt. 11B
****

Mic #	Angle (deg)	Distance (m)	Flatpeak (dB)	Apeak (dB)	ASEL (dB)	FSEL (dB)
1	90.0	50.0	125.0	124.2	91.1	95.0
2	90.0	128.0	103.7	91.6	64.4	79.4
4	120.0	50.0	125.7	123.8	89.6	92.4
5	120.0	128.0	100.6	91.7	63.8	75.5

INSERTION LOSS
****

Angle (deg)	Distance (m)	Flatpeak (dB)	Apeak (dB)	ASEL (dB)	FSEL (dB)
90.0	50.0	2.6	2.3	3.4	2.8
90.0	128.0	22.5	32.6	24.4	12.6
120.0	50.0	0.8	2.4	4.8	4.6
120.0	128.0	21.6	28.8	21.6	12.1

Table A6.

EXPT:	Camp Grayling, 50 caliber Range 35 (High berm).
DATE:	6-11-91 Expts 11B,12B for comparison of propagation conditions.
GUN @:	Ring mount, DOF 0°. Berm to the side.
WIND:	270°, 2-4 meters/sec.

SHIELDED GUN Expt. 11B
****

Mic #	Angle (deg)	Distance (m)	Flatpeak (dB)	Apeak (dB)	ASEL (dB)	FSEL (dB)
1	90.0	50.0	124.8	124.3	91.1	95.0
2	90.0	128.0	103.8	91.6	64.4	79.4
4	120.0	50.0	125.6	123.7	89.5	92.3
5	120.0	128.0	100.6	91.8	63.9	75.5

SHIELDED GUN Expt. 12B
****

Mic #	Angle (deg)	Distance (m)	Flatpeak (dB)	Apeak (dB)	ASEL (dB)	FSEL (dB)
1	90.0	50.0	125.0	124.6	91.1	94.9
2	90.0	128.0	103.7	90.6	64.3	79.1
4	120.0	50.0	124.4	120.4	87.3	91.7
5	120.0	128.0	100.7	92.0	64.1	75.2

CHANGE IN CONDITIONS
****

Angle (deg)	Distance (m)	Flatpeak (dB)	Apeak (dB)	ASEL (dB)	FSEL (dB)
90.0	50.0	-0.2	-0.3	0.0	0.1
90.0	128.0	0.1	1.0	0.1	0.3
120.0	50.0	1.2	3.3	2.2	0.6
120.0	128.0	-0.1	-0.2	-0.2	0.3

Table A7.

EXPT.	Camp Grayling, 50 caliber	Range 37 (Low berm).
DATE:	6-12-91 Experiment 3.	
GUN @:	Tripod mount, DOF 0°. Berm to the rear.	
WIND:	280°, 2-4 meters/sec.	

UNSHIELDED GUN Expt. 3
****

Mic #	Angle (deg)	Distance (m)	Flatpeak (dB)	Apeak (dB)	ASEL (dB)	FSEL (dB)
1	180.0	7.0	145.5	143.8	107.7	111.3
3	180.0	53.0	119.2	117.1	84.0	91.0
6	177.5	159.0	105.1	100.0	72.0	78.1
4	240.0	106.0	114.0	104.0	74.7	86.0
7	208.0	180.0	101.0	92.0	64.1	76.6

SHIELDED GUN Expt. 3
****

Mic #	Angle (deg)	Distance (m)	Flatpeak (dB)	Apeak (dB)	ASEL (dB)	FSEL (dB)
2	180.0	7.0	146.5	144.3	111.7	114.3
4	180.0	53.0	113.5	105.3	76.0	86.9
7	177.5	159.0	99.2	89.7	61.2	75.6
5	240.0	106.0	110.0	101.4	70.2	83.4
8	208.0	180.0	97.9	86.6	57.7	73.3

INSERTION LOSS
****

Angle (deg)	Distance (m)	Flatpeak (dB)	Apeak (dB)	ASEL (dB)	FSEL (dB)
180.0	7.0	-1.0	-0.5	-4.0	-3.0
180.0	53.0	5.7	11.8	8.0	4.1
177.5	159.0	5.9	10.3	10.8	2.5
240.0	106.0	4.0	2.6	4.5	2.6
208.0	180.0	3.1	5.4	6.4	3.3

Table A8.

EXPT.	Camp Grayling, 50 caliber	Range 35 (High berm).
DATE:	6–12–91 Experiments 6A,7B.	
GUN @:	Ring mount, DOF 0°. Berm to the side.	
WIND:	0°, 4–7 meters/sec.	

UNSHIELDED GUN Expt. 6A

****

Mic #	Angle (deg)	Distance (m)	Flatpeak (dB)	Apeak (dB)	ASEL (dB)	FSEL (dB)
7	90.0	50.0	136.2	135.1	98.8	101.6
8	90.0	128.0	126.6	124.8	87.0	90.9
10	120.0	50.0	132.1	130.9	95.6	97.8
11	120.0	128.0	124.8	123.1	87.4	89.1

SHIELDED GUN Expt. 7B

****

Mic #	Angle (deg)	Distance (m)	Flatpeak (dB)	Apeak (dB)	ASEL (dB)	FSEL (dB)
1	90.0	50.0	135.7	134.5	96.2	98.6
2	90.0	128.0	103.8	91.4	64.9	79.5
4	120.0	50.0	126.2	123.8	90.4	93.3
5	120.0	128.0	100.5	92.5	65.5	75.4

INSERTION LOSS

****

Angle (deg)	Distance (m)	Flatpeak (dB)	Apeak (dB)	ASEL (dB)	FSEL (dB)
90.0	50.0	0.5	0.6	2.6	3.0
90.0	128.0	22.8	33.4	22.1	11.4
120.0	50.0	5.9	7.1	5.2	4.5
120.0	128.0	24.3	30.6	21.9	13.7

Table A9.

EXPT.	Camp Grayling, 50 caliber Range 35 (High berm).
DATE:	6-12-91 Expts 6B,7B for comparison of propagation conditions.
GUN @:	Ring mount, DOF 0°. Berm to the side.
WIND:	Expt. 6B, 250°, 4-7 meters/sec.; Expt. 7B, 0°, 4-7 meters/sec.

SHIELDED GUN Test 6B
****

Mic #	Angle (deg)	Distance (m)	Flatpeak (dB)	Apeak (dB)	ASEL (dB)	FSEL (dB)
1	90.0	50.0	135.4	134.2	96.7	99.7
2	90.0	128.0	106.7	97.6	68.9	80.6
4	120.0	50.0	126.6	124.4	90.6	93.0
5	120.0	128.0	101.8	97.0	67.8	76.2

SHIELDED GUN Test 7B
****

Mic #	Angle (deg)	Distance (m)	Flatpeak (dB)	Apeak (dB)	ASEL (dB)	FSEL (dB)
1	90.0	50.0	135.7	134.5	96.2	98.6
2	90.0	128.0	103.8	91.4	64.9	79.5
4	120.0	50.0	126.2	123.8	90.4	93.3
5	120.0	128.0	100.5	92.5	65.5	75.4

CHANGE IN CONDITIONS
****

Angle (deg)	Distance (m)	Flatpeak (dB)	Apeak (dB)	ASEL (dB)	FSEL (dB)
90.0	50.0	-0.3	-0.3	0.5	1.1
90.0	128.0	2.9	6.2	4.0	1.1
120.0	50.0	0.4	0.6	0.2	-0.3
120.0	128.0	1.3	4.5	2.3	0.8

Table A10.

TEST:	Camp Grayling, 50 caliber	Range 35 (High berm).
DATE:	6-13-91 Experiments 2B, 3A.	
GUN @:	Ring mount, DOF 0°. Berm to the side.	
WIND:	90°, 2-4 meters/sec.	

UNSHIELDED GUN Expt. 3A
****

Mic #	Angle (deg)	Distance (m)	Flatpeak (dB)	Apeak (dB)	ASEL (dB)	FSEL (dB)
7	90.0	50.0	135.4	134.0	96.8	100.8 CLIPPED
8	90.0	128.0	118.8	111.5	79.2	88.0
10	120.0	50.0	133.8	132.3	95.8	97.6
11	120.0	128.0	115.8	110.0	76.8	84.3

SHIELDED GUN Expt. 2B
****

Mic #	Angle (deg)	Distance (m)	Flatpeak (dB)	Apeak (dB)	ASEL (dB)	FSEL (dB)
1	90.0	50.0	133.4	132.2	93.9	97.2
2	90.0	128.0	102.9	88.5	63.0	78.8
4	120.0	50.0	124.0	119.7	87.1	91.3
5	120.0	128.0	99.7	90.5	63.5	75.3

INSERTION LOSS
****

Angle (deg)	Distance (m)	Flatpeak (dB)	Apeak (dB)	ASEL (dB)	FSEL (dB)
90.0	50.0	2.0	1.8	2.9	3.6
90.0	128.0	15.9	23.0	16.2	9.2
120.0	50.0	9.8	12.6	8.7	6.3
120.0	128.0	16.1	19.5	13.3	9.0

Table A11.

TEST:	Camp Grayling, 50 caliber	Range 35 (High berm).
DATE:	6–13–91 Experiments 2B, 4A.	
GUN @:	Ring mount, DOF 0°. Berm to the side.	
WIND:	90°, 2–4 meters/sec.	

UNSHIELDED GUN Expt. 4A
****

Mic #	Angle (deg)	Distance (m)	Flatpeak (dB)	Apeak (dB)	ASEL (dB)	FSEL (dB)
7	90.0	50.0	135.9	134.6	98.1	101.0
8	90.0	128.0	120.1	114.8	81.1	88.1
10	120.0	50.0	133.7	131.6	96.7	98.6
11	120.0	128.0	119.0	116.7	81.6	86.4

SHIELDED GUN Expt. 2B
****

Mic #	Angle (deg)	Distance (m)	Flatpeak (dB)	Apeak (dB)	ASEL (dB)	FSEL (dB)
1	90.0	50.0	133.4	132.2	93.9	97.2
2	90.0	128.0	102.9	88.5	63.0	78.8
4	120.0	50.0	124.0	119.7	87.1	91.3
5	120.0	128.0	99.7	90.5	63.5	75.3

INSERTION LOSS
****

Angle (deg)	Distance (m)	Flatpeak (dB)	Apeak (dB)	ASEL (dB)	FSEL (dB)
90.0	50.0	2.5	2.4	4.2	3.8
90.0	128.0	17.2	26.3	18.1	9.3
120.0	50.0	9.7	11.9	9.6	7.3
120.0	128.0	19.3	26.2	18.1	11.1

Table A12.

TEST:	Camp Grayling, 50 caliber Range 35 (High berm).
DATE:	6-13-91 Expts 3A,4A for comparison of propagation conditions.
GUN @:	Ring mount, DOF 0°. Berm to the side.
WIND:	90°, 2-4 meters/sec.

UNSHIELDED GUN Expt. 3A
****

Mic #	Angle (deg)	Distance (m)	Flatpeak (dB)	Apeak (dB)	ASEL (dB)	FSEL (dB)
7	90.0	50.0	135.4	134.0	96.8	100.8 CLIPPED
8	90.0	128.0	118.8	111.5	79.2	88.0
10	120.0	50.0	133.8	132.3	95.8	97.6
11	120.0	128.0	115.8	110.0	76.8	84.3

UNSHIELDED GUN Expt. 4A
****

Mic #	Angle (deg)	Distance (m)	Flatpeak (dB)	Apeak (dB)	ASEL (dB)	FSEL (dB)
7	90.0	50.0	135.9	134.6	98.1	101.0 CLIPPED
8	90.0	128.0	120.1	114.8	81.1	88.1
10	120.0	50.0	133.7	131.6	96.7	98.6
11	120.0	128.0	118.9	116.2	81.4	86.1

CHANGE IN CONDITIONS
****

Angle (deg)	Distance (m)	Flatpeak (dB)	Apeak (dB)	ASEL (dB)	FSEL (dB)
90.0	50.0	-0.5	-0.6	-1.3	-0.2
90.0	128.0	-1.3	-3.3	-1.9	-0.1
120.0	50.0	0.1	0.7	-0.9	-1.0
120.0	128.0	-3.1	-6.2	-4.6	-1.8

Table A13.

TEST:	Camp Grayling, 50 caliber	Range 35 (High berm).
DATE:	6–13–91 Experiments 5A,4B.	
GUN @:	Tripod mount, DOF 0°. Berm to the side.	
WIND:	90°, 2–4 meters/sec.	

UNSHIELDED GUN Expt. 5A
****

Mic #	Angle (deg)	Distance (m)	Flatpeak (dB)	Apeak (dB)	ASEL (dB)	FSEL (dB)
7	90.0	50.0	126.8	122.5	89.1	99.5
8	90.0	128.0	114.8	104.1	75.1	89.2
10	120.0	50.0	125.2	119.6	86.2	96.2
11	120.0	128.0	112.3	99.7	72.2	85.6

SHIELDED GUN Expt. 4B
****

Mic #	Angle (deg)	Distance (m)	Flatpeak (dB)	Apeak (dB)	ASEL (dB)	FSEL (dB)
1	90.0	50.0	123.4	118.4	84.5	96.8
2	90.0	128.0	104.6	87.8	63.2	81.8
4	120.0	50.0	119.2	113.3	82.7	93.3
5	120.0	128.0	101.8	91.1	63.4	78.3

LEVEL DIFFERENCE
****

Angle (deg)	Distance (m)	Flatpeak (dB)	Apeak (dB)	ASEL (dB)	FSEL (dB)
90.0	50.0	3.4	4.1	4.6	2.7
90.0	128.0	10.2	16.3	11.9	7.4
120.0	50.0	6.0	6.3	3.5	2.9
120.0	128.0	10.5	8.6	8.8	7.3

Table A14.

TEST:	Camp Grayling, 50 caliber	Range 37 (Low berm).
DATE:	6–13–91 Experiment 12.	
GUN @:	Tripod mount, DOF 0°. Berm to the rear.	
WIND:	90°, 2–4 meters/sec.	

UNSHIELDED GUN Expt. 12
****

Mic #	Angle (deg)	Distance (m)	Flatpeak (dB)	Apeak (dB)	ASEL (dB)	FSEL (dB)
1	180.0	7.0	144.6	142.3	107.9	111.4
3	180.0	53.0	116.5	109.7	79.7	90.1
6	177.5	159.0	100.6	87.9	61.1	76.0
4	240.0	106.0	115.0	107.9	76.9	87.6
7	208.0	180.0	100.9	87.9	61.5	76.4

SHIELDED GUN Expt. 12
****

Mic #	Angle (deg)	Distance (m)	Flatpeak (dB)	Apeak (dB)	ASEL (dB)	FSEL (dB)
2	180.0	7.0	146.7	144.6	112.2	114.1
4	180.0	53.0	110.7	103.0	74.9	85.3
7	177.5	159.0	95.8	79.8	55.6	72.5
5	240.0	106.0	109.6	102.0	70.3	84.1
8	208.0	180.0	97.2	82.6	56.6	73.2

INSERTION LOSS
****

Angle (deg)	Distance (m)	Flatpeak (dB)	Apeak (dB)	ASEL (dB)	FSEL (dB)
180.0	7.0	−2.1	−2.3	−4.3	−2.7
180.0	53.0	5.8	6.7	4.8	4.8
177.5	159.0	4.8	8.1	5.5	3.5
240.0	106.0	5.4	5.9	6.6	3.5
208.0	180.0	3.7	5.3	4.9	3.2

Table A15.

EXPT:	Camp Grayling, 50 caliber Range 35 (High berm).
DATE:	6-29-91 Experiment 3A, mic pole, for path height comparison.
GUN @:	Tripod and Ring mount firing downrange (DOF 0°) at A.
WIND:	70°, 0-2 meters/sec.

RING MOUNTED GUN Expt. 3A

****

Mic #	Angle (deg)	Distance (m)	Flatpeak (dB)	Apeak (dB)	ASEL (dB)	FSEL (dB)
7	90.0	50.0	136.5	135.2	98.5	101.3
8	90.0	128.0	122.2	118.7	83.4	89.3 MID 51"
10	120.0	50.0	133.0	131.8	96.1	98.3
11	120.0	128.0	120.5	118.6	83.0	86.2
13	90.0	128.0	116.2	107.7	76.5	88.9 LOW 13"
14	90.0	128.0	128.8	127.1	90.2	92.2 HIGH 124"

TRIPOD MOUNTED GUN Expt. 3A

****

Mic #	Angle (deg)	Distance (m)	Flatpeak (dB)	Apeak (dB)	ASEL (dB)	FSEL (dB)
7	90.0	50.0	126.2	120.2	88.5	99.4
8	90.0	128.0	115.0	102.8	75.0	89.1 MID 51"
10	120.0	50.0	123.8	120.3	85.9	95.4
11	120.0	128.0	110.5	101.7	71.2	84.4
13	90.0	128.0	115.5	99.5	75.5	89.8 LOW 13"
14	90	128	116.3	107.6	76.8	88.5 HIGH 124"

LEVEL DIFFERENCE

****

Angle (deg)	Distance (m)	Flatpeak (dB)	Apeak (dB)	ASEL (dB)	FSEL (dB)
90.0	50.0	10.3	15.0	10.0	1.9
90.0	128.0	7.2	15.9	8.4	0.2 MID 51"
120.0	50.0	9.2	11.5	10.2	2.9
120.0	128.0	10.0	16.9	11.8	1.8
90.0	128.0	0.7	8.2	1.0	-0.9 LOW 13"
90.0	128.0	12.5	19.5	13.4	3.7 HIGH 124"

Table A16.

EXPT:	Camp Grayling, 50 caliber	Range 35 (High berm).
DATE:	6-29-91 Experiment 4A, Tripod only, for comparison with 3A.	
GUN @:	Tripod mount only, firing downrange (DOF 0°) at A.	
WIND:	70°, 0-3 meters/sec.	

TRIPOD, NO VEHICLE Expt. 4A
****

Mic #	Angle (deg)	Distance (m)	Flatpeak (dB)	Apeak (dB)	ASEL (dB)	FSEL (dB)
7	90.0	50.0	126.9	120.7	88.7	99.3
8	90.0	128.0	114.5	101.9	74.3	88.5 MID 51"
10	120.0	50.0	123.4	118.7	85.4	95.3
11	120.0	128.0	110.6	100.2	71.0	84.0
13	90.0	128.0	114.7	98.7	74.6	89.1 LOW 13"
14	90.0	128.0	115.8	106.6	76.3	88.2 HIGH 124"

TRIPOD, WITH VEHICLE Expt. 3A
****

Mic #	Angle (deg)	Distance (m)	Flatpeak (dB)	Apeak (dB)	ASEL (dB)	FSEL (dB)
7	90.0	50.0	126.2	120.2	88.5	99.4
8	90.0	128.0	115.0	102.8	75.0	89.1 MID 51"
10	120.0	50.0	123.8	120.3	85.9	95.4
11	120.0	128.0	110.5	101.7	71.2	84.4
13	90.0	128.0	115.5	99.5	75.5	89.8 LOW 13"
14	90.0	128.0	116.3	107.6	76.8	88.5 HIGH 124"

LEVEL DIFFERENCE
****

Angle (deg)	Distance (m)	Flatpeak (dB)	Apeak (dB)	ASEL (dB)	FSEL (dB)
90.0	50.0	0.7	0.5	0.2	-0.1
90.0	128.0	-0.5	-0.9	-0.7	-0.6 MID 51"
120.0	50.0	-0.4	-1.6	-0.5	-0.1
120.0	128.0	0.1	-1.5	-0.2	-0.4
90.0	128.0	-0.8	-0.8	-0.9	-0.7 LOW 13"
90.0	128.0	-0.5	-1.0	0.1	-0.3 HIGH 124"

Table A17.

EXPT:	Camp Grayling, 50 caliber Range 35 (High berm).
DATE:	6–29–91 Expt 5A, mic pole, for path height comparison (Repeat of 3A).
GUN @:	Tripod and Ring mount firing downrange (DOF 0°) at A.
WIND:	70°, 0–4 meters/sec.

RING MOUNTED GUN Expt. 5A
****

Mic #	Angle (deg)	Distance (m)	Flatpeak (dB)	Apeak (dB)	ASEL (dB)	FSEL (dB)
7	90.0	50.0	136.9	135.5	98.0	101.1
8	90.0	128.0	117.7	110.9	78.4	87.9 MID 51"
10	120.0	50.0	133.4	131.9	96.2	98.1
11	120.0	128.0	116.9	113.1	80.6	84.8
13	90.0	128.0	115.2	102.3	75.1	88.0 LOW 13"
14	90.0	128.0	124.8	121.6	86.2	89.9 HIGH 124"

TRIPOD MOUNTED GUN Expt. 5A
****

Mic #	Angle (deg)	Distance (m)	Flatpeak (dB)	Apeak (dB)	ASEL (dB)	FSEL (dB)
7	90.0	50.0	126.5	117.8	88.3	99.1
8	90.0	128.0	114.3	100.6	73.9	88.0 MID 51"
10	120.0	50.0	123.1	117.6	85.0	94.9
11	120.0	128.0	110.7	100.1	71.4	84.0
13	90.0	128.0	114.2	97.2	74.0	88.4 LOW 13"
14	90.0	128.0	115.6	103.5	75.9	87.9 HIGH 124"

LEVEL DIFFERENCE
****

Angle (deg)	Distance (m)	Flatpeak (dB)	Apeak (dB)	ASEL (dB)	FSEL (dB)
90.0	50.0	10.4	17.7	9.7	2.0
90.0	128.0	3.4	10.3	4.5	−0.1 MID 51"
120.0	50.0	10.3	14.3	11.2	3.2
120.0	128.0	6.2	13.0	9.2	0.8
90.0	128.0	1.0	5.1	1.1	−0.4 LOW 13"
90.0	128.0	9.2	18.1	10.3	2.0 HIGH 124"

Table A18.

EXPT:	Camp Grayling, 50 caliber	Range 35 (High berm).
DATE:	6-29-91 Experiments 8A,8B.	
GUN @:	Ring mount, DOF 0°. Berm to the side.	
WIND:	150°, 2-4 meters/sec.	

UNSHIELDED GUN Expt. 8A
****

Mic #	Angle (deg)	Distance (m)	Flatpeak (dB)	Apeak (dB)	ASEL (dB)	FSEL (dB)
7	90.0	50.0	137.2	136.0	98.4	101.6
8	90.0	128.0	117.5	110.9	78.2	88.0
10	120.0	50.0	133.5	131.7	95.6	97.4
11	120.0	128.0	112.7	106.7	74.5	83.3

SHIELDED GUN Expt. 8B
****

Mic #	Angle (deg)	Distance (m)	Flatpeak (dB)	Apeak (dB)	ASEL (dB)	FSEL (dB)
1	90.0	50.0	128.7	125.8	90.4	95.8
2	90.0	128.0	102.7	87.1	62.3	78.5
4	120.0	50.0	103.0	99.0	66.5	71.4
5	120.0	128.0	100.3	92.3	64.1	74.7

LEVEL DIFFERENCE
****

Angle (deg)	Distance (m)	Flatpeak (dB)	Apeak (dB)	ASEL (dB)	FSEL (dB)
90.0	50.0	8.5	10.2	8.0	5.8
90.0	128.0	14.8	23.8	15.9	9.5
120.0	50.0	30.5	32.7	29.1	26.0
120.0	128.0	12.4	14.4	10.4	8.6

Table A19.

EXPT:	Camp Grayling, 50 caliber Range 35 (High berm).
DATE:	6–29–91 Experiments 9A,9B.
GUN @:	Tripod mount, DOF 0°. Berm to the side.
WIND:	150°, 1–4 meters/sec.

UNSHIELDED GUN   Expt. 9A

****

Mic #	Angle (deg)	Distance (m)	Flatpeak (dB)	Apeak (dB)	ASEL (dB)	FSEL (dB)
7	90.0	50.0	128.9	127.3	91.0	99.9
8	90.0	128.0	117.2	113.9	78.8	89.7
10	120.0	50.0	123.5	119.3	85.5	95.3
11	120.0	128.0	110.8	100.2	71.3	84.3

SHIELDED GUN   Expt. 9B

****

Mic #	Angle (deg)	Distance (m)	Flatpeak (dB)	Apeak (dB)	ASEL (dB)	FSEL (dB)
1	90.0	50.0	123.9	121.3	85.4	96.6
2	90.0	128.0	104.4	86.4	62.7	81.3
4	120.0	50.0	97.6	89.5	61.2	72.6
5	120.0	128.0	101.5	91.0	62.6	77.6

LEVEL DIFFERENCE

****

Angle (deg)	Distance (m)	Flatpeak (dB)	Apeak (dB)	ASEL (dB)	FSEL (dB)
90.0	50.0	5.0	6.0	5.6	3.3
90.0	128.0	12.8	27.5	16.1	8.4
120.0	50.0	25.9	29.8	24.3	22.7
120.0	128.0	9.3	9.2	8.7	6.7

Table A20.

EXPT:	Camp Grayling, 50 caliber	Range 35 (High berm).
DATE:	6–29–91 Experiment 10.	
GUN @:	Tripod mount, DOF 270°. Berm to the rear.	
WIND:	150°, 1–4 meters/sec.	

UNSHIELDED GUN Expt 10.
****

Mic #	Angle (deg)	Distance (m)	Flatpeak (dB)	Apeak (dB)	ASEL (dB)	FSEL (dB)
7	90.0	50.0	119.2	117.6	82.9	90.1
8	90.0	128.0	105.6	99.5	69.4	80.2
10	120.0	50.0	120.0	116.3	83.3	91.4
11	120.0	128.0	106.2	97.0	67.6	79.9

SHIELDED GUN Expt 10.
****

Mic #	Angle (deg)	Distance (m)	Flatpeak (dB)	Apeak (dB)	ASEL (dB)	FSEL (dB)
1	90.0	50.0	117.4	115.1	82.6	91.1
2	90.0	128.0	97.5	81.8	58.0	74.0
4	120.0	50.0	95.5	87.4	60.4	70.4
5	120.0	128.0	99.5	89.2	61.1	74.5

LEVEL DIFFERENCE
****

Angle (deg)	Distance (m)	Flatpeak (dB)	Apeak (dB)	ASEL (dB)	FSEL (dB)
90.0	50.0	1.8	2.5	0.3	−1.0
90.0	128.0	8.1	17.7	11.4	6.2
120.0	50.0	24.5	28.9	22.9	21.0
120.0	128.0	6.7	7.8	6.5	5.4

Table A21.

EXPT:	Camp Grayling, 50 caliber	Range 35 (High berm).
DATE:	6-29-91 Experiment 15A for gun comparison.	
GUN @:	Tripod mount, DOF 0°. Berm to the side.	
WIND:	150°, 1-4 meters/sec.	

UNSHIELDED GUN (RIGHT) Expt. 15A

****

Mic #	Angle (deg)	Distance (m)	Flatpeak (dB)	Apeak (dB)	ASEL (dB)	FSEL (dB)
7	90.0	50.0	127.0	120.5	88.9	99.2
8	90.0	128.0	113.9	100.8	73.7	87.5
10	120.0	50.0	123.0	115.4	84.4	94.3
11	120.0	128.0	108.2	96.4	68.6	81.8

UNSHIELDED GUN (LEFT) Expt. 15A

****

Mic #	Angle (deg)	Distance (m)	Flatpeak (dB)	Apeak (dB)	ASEL (dB)	FSEL (dB)
7	90.0	50.0	125.8	118.5	87.3	98.0
8	90.0	128.0	113.4	100.2	73.0	87.0
10	120.0	50.0	122.6	115.6	84.2	94.2
11	120.0	128.0	108.1	95.6	68.4	81.8

GUN DIFFERENCE

****

Angle (deg)	Distance (m)	Flatpeak (dB)	Apeak (dB)	ASEL (dB)	FSEL (dB)
90.0	50.0	1.2	2.0	1.6	1.2
90.0	128.0	0.5	0.6	0.7	0.5
120.0	50.0	0.4	-0.2	0.2	0.1
120.0	128.0	0.1	0.8	0.2	0.0

Table A22.

EXPT:	Camp Grayling, 50 caliber Range 35 (High berm).
DATE:	6–29–91 Experiment 16A, mic pole, for path height comparison.
GUN @:	Tripod and Ring mount firing downrange (DOF 0°) at A.
WIND:	150°, 2–4 meters/sec.

RING MOUNTED GUN Expt. 16A
****

Mic #	Angle (deg)	Distance (m)	Flatpeak (dB)	Apeak (dB)	ASEL (dB)	FSEL (dB)
7	90.0	50.0	135.4	133.9	97.5	100.7
8	90.0	128.0	118.3	112.9	79.9	87.8 MID 51"
10	120.0	50.0	133.8	131.7	95.5	97.6
11	120.0	128.0	111.3	101.5	72.9	82.5
13	90.0	128.0	115.2	104.5	75.4	88.0 LOW 13"
14	90.0	128.0	124.1	120.8	85.8	89.6 HIGH 124"

TRIPOD MOUNTED GUN Expt. 16A
****

Mic #	Angle (deg)	Distance (m)	Flatpeak (dB)	Apeak (dB)	ASEL (dB)	FSEL (dB)
7	90.0	50.0	127.5	121.8	89.5	99.4
8	90.0	128.0	114.7	101.4	74.4	88.2 MID 51"
10	120.0	50.0	122.7	116.5	84.6	94.2
11	120.0	128.0	107.2	93.8	67.1	81.2
13	90.0	128.0	115.1	98.8	74.9	89.0 LOW 13"
14	90.0	128.0	116.3	107.3	76.8	88.0 HIGH 124"

LEVEL DIFFERENCE
****

Angle (deg)	Distance (m)	Flatpeak (dB)	Apeak (dB)	ASEL (dB)	FSEL (dB)
90.0	50.0	7.9	12.1	8.0	1.3
90.0	128.0	3.6	11.5	5.5	−0.4 MID 51"
120.0	50.0	11.1	15.2	10.9	3.4
120.0	128.0	4.1	7.7	5.8	1.3
90.0	128.0	0.1	5.7	0.5	−1.0 LOW 13"
90.0	128.0	7.8	13.5	9.0	1.6 HIGH 124"

Table A23.

EXPT:	Camp Grayling, 50 caliber	Range 37 (Low berm).
DATE:	6-30-91. Expt. 21	
GUN @:	Tripod mount, DOF 0°. Berm to the rear.	
WIND:	45°, 1-3 meters/sec.	

UNSHIELDED GUN Expt. 21

****

Mic #	Angle (deg)	Distance (m)	Flatpeak (dB)	Apeak (dB)	ASEL (dB)	FSEL (dB)
1	180.0	7.0	145.2	143.1	109.0	111.9
3	180.0	53.0	122.1	121.1	86.8	91.8
6	177.5	159.0	108.1	106.0	76.1	79.7
4	240.0	106.0	117.5	115.2	79.8	88.2
7	208.0	180.0	107.9	105.1	74.8	79.7

SHIELDED GUN Expt. 21

****

Mic #	Angle (deg)	Distance (m)	Flatpeak (dB)	Apeak (dB)	ASEL (dB)	FSEL (dB)
2	180.0	7.0	146.4	144.2	110.7	113.5
4	180.0	53.0	113.9	106.0	76.5	87.2
7	177.5	159.0	100.7	91.3	63.9	75.8
5	240.0	106.0	112.6	108.3	75.1	85.7
8	208.0	180.0	101.8	94.6	64.8	76.5

INSERTION LOSS

****

Angle (deg)	Distance (m)	Flatpeak (dB)	Apeak (dB)	ASEL (dB)	FSEL (dB)
180.0	7.0	-1.2	-1.1	-1.7	-1.6
180.0	53.0	8.2	15.1	10.3	4.6
177.5	159.0	7.4	14.7	12.2	3.9
240.0	106.0	4.9	6.9	4.7	2.5
208.0	180.0	6.1	10.5	10.0	3.2

Table A24.

EXPT:	Camp Grayling, 50 caliber	Range 37 (Low berm).	
DATE:	6–30–91 Expt. 22.		
GUN @:	Tripod mount, DOF 0°. Berm to the rear.		FULL AUTO BURST.
WIND:	45°, 3 meters/sec.		

UNSHIELDED GUN Expt. 22

****

Mic #	Angle (deg)	Distance (m)	Flatpeak (dB)	Apeak (dB)	ASEL (dB)	FSEL (dB)
1	180.0	7.0	145.9	143.9	117.1	119.7
3	180.0	53.0	122.0	120.7	93.9	98.8
6	177.5	159.0	109.7	106.2	80.2	85.8
4	240.0	106.0	116.7	112.2	85.9	95.5
7	208.0	180.0	107.3	104.0	81.1	86.7

SHIELDED GUN Expt. 22

****

Mic #	Angle (deg)	Distance (m)	Flatpeak (dB)	Apeak (dB)	ASEL (dB)	FSEL (dB)
2	180.0	7.0	147.9	145.5	119.1	121.8
4	180.0	53.0	114.4	108.4	85.1	94.9
7	177.5	159.0	100.3	94.9	71.8	82.8
5	240.0	106.0	111.5	104.8	80.7	92.6
8	208.0	180.0	100.8	96.1	71.6	83.6

INSERTION LOSS

****

Angle (deg)	Distance (m)	Flatpeak (dB)	Apeak (dB)	ASEL (dB)	FSEL (dB)
180.0	7.0	−2.0	−1.6	−2.0	−2.1
180.0	53.0	7.6	12.3	8.8	3.9
177.5	159.0	9.4	11.3	8.4	3.0
240.0	106.0	5.2	7.4	5.2	2.9
208.0	180.0	6.5	7.9	9.5	3.1

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